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[624 .2]

Calculation of continuous girders carried on columns rigidly held at their bases [1],

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Figs. 1 to 6, pp. 3 to 7.

The *Bulletin of the International Railway Congress Association* for January 1929 published a paper on triplespan reinforced concrete bridges carried on four columns rigidly held at their bases, written by Messrs. F. Berger, Chief Engineer of the Belgian National Railway Company, and P. Van Weyenberghe, Agricultural Hydraulics Engineer.

This system being 9 times hyperstatic, there are in consequence 9 redundant stresses to be determined. The calculation, which was made with quite remarkable patience, leads to the solution of the 9 unknowns, and represents an exceedingly long piece of work despite the symmetry of the structure in question. It is very probable that if the structure had not been symmetrical, the calculation would have led to the solution of a system of 9 equations, a formidable piece of work which would increase considerably the risk of errors. It is of interest, therefore, to find methods for reducing the number of the equations.

Basing our arguments on the equations of elasticity of Maxwell and Müller-Breslau, to be found in the excellent work by Müller-Breslau : *Neuere Methode der Festigkeitslehre* and which we have developed and made use of on various occasions in the *Génie Civil*, the *Technique des Travaux* and the *Schweizerische Bauzeitung* [2], we arrive at calculations

(1) Translated from the French.

(2) Vide, in this connection :

1. The *Génie Civil* for 11 February 1922 : Calcul des poutres à treillis double avec membrures parallèles et montants verticaux à tous les nœuds d'attache. (The calculation of double lattice girders with parallel flanges and vertical struts at all the joints);
2. The *Génie Civil* for 6 January 1923 : La poutre à treillis à membrures parallèles calculée comme système élastique (The lattice girder with parallel flanges calculated as an elastic system);
3. The *Technique des Travaux* for March 1928 · Etude sur le calcul des systèmes hyperstatiques (Study on the calculation of hyperstatic systems);
4. The *Schweizerische Bauzeitung* for 25 December 1926 : Nouveau calcul de l'arc à tirant faisant partie du tablier. (New calculation of the arched girder with tie member forming part of the bridge).

comprising not more than three equations.

The n redundant stresses X_a, X^b, X_c ... X_n of a system which is n times hyperstatic, stressed by loads P_1, P_2, P_3 ... P_m may be represented by the well-known equations:

$$\left.\begin{array}{l} X_a\delta_{aa} + X_b\delta_{ab} + X_c\delta_{ac} + \ldots\ldots X_n\delta_{an} = \Sigma P_m\delta_{ma} \\ X_a\delta_{ba} + X_b\delta_{bb} + X_c\delta_{bc} + \ldots\ldots X_n\delta_{bn} = \Sigma P_m\delta_{mb} \\ \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \\ \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \\ X_a\delta_{na} + X_b\delta_{nb} + X_c\delta_{nc} + \ldots X_n\delta_{nn} = \Sigma P_m\delta_{mn} \end{array}\right\} \ldots\ldots \quad (1)$$

The values δ represent the displacements. For example, δ_{ac} is the displacement of the point of application of the stress X_c in the direction of X_c and due to $X_a = -1$. According to Maxwell, it is also: $\delta_{mn} = \delta_{nm}$.

Instead of applying our equations to the 9 redundant stresses of a principal isostatic system, we can apply them equally well to a principal system already m times hyperstatic, such that the number of redundant stresses will not be greater than $9 - m$.

Naturally, the principal hyperstatic system will have to be easy to calculate, otherwise we run the risk of making the work complicated. Now the doubly fixed gantry, even if unsymmetrical offers no difficulty at all. If it is symmetrical we can at once write down the stresses for whatever load according to the usual equations.

That being so. we select as principal system the two lateral openings to which we shall apply, as redundant stresses, the moments X_a, X_b and the normal stress H_2 of the central girder.

In order to make the equations more uniform, we shall not select H_2 as an unknown but a moment:

$$H_2 \cdot h_a = X_c \quad \ldots\ldots (2)$$

Putting: $\Sigma P_m\delta_{ma} = \delta_{oa}$, $\Sigma P_m\delta_{mb} = \delta_{ob}$ etc., we obtain for our three equations:

$$\left.\begin{array}{l} X_a\delta_{aa} + X_b\delta_{ab} + X_c\delta_{ac} = \delta_{oa} \\ X_a\delta_{ba} + X_b\delta_{bb} + X\,\delta_{bc} = \delta_{ob} \\ X_a\delta_{ca} + X_b\delta_{cb} + X_c\delta_{cc} = \delta_{oc} \end{array}\right\} \quad (3)$$

These three equations enable us to calculate X_a, X_b, and X_c, for any condition of load. If it is a question of ascertaining the effect of the supports being out of level, or of variations in temperature, it is merely necessary to introduce other terms for δ_{oa}, δ_{ob} and δ_{oc} [1].

In accordance with the calculation of determinants, we write:

$$\left.\begin{array}{l} X_a = \alpha_{aa}\delta_{oa} + \alpha_{ab}\delta_{ob} + \alpha_{ac}\delta_{oc} \\ X_b = \alpha_{ba}\delta_{oa} + \alpha_{bb}\delta_{ob} + \alpha_{bc}\delta_{oc} \\ X_c = \alpha_{ca}\delta_{oa} + \alpha_{cb}\delta_{ob} + \alpha_{cc}\delta_{oc} \end{array}\right\} \quad (4)$$

with:

$$\Delta = \begin{vmatrix} \delta_{aa} & \delta_{ab} & \delta_{ac} \\ \delta_{ba} & \delta_{bb} & \delta_{bc} \\ \delta_{ca} & \delta_{cb} & \delta_{cc} \end{vmatrix} \quad \ldots (5)$$

and

$$\Delta \cdot \alpha_{aa} = \begin{vmatrix} \delta_{bb} & \delta_{bc} \\ \delta_{cb} & \delta_{cc} \end{vmatrix}$$

$$\Delta \cdot \alpha_{ba} = - \begin{vmatrix} \delta_{ab} & \delta_{ac} \\ \delta_{cb} & \delta_{cc} \end{vmatrix} \quad \text{etc.}$$

The coefficients α_{aa}, α_{ab} ... will therefore be calculated once and for all for the sys-

(1) Vide in this connection: *The Génie Civil* for 30 June, 1923: « Calcul de l'arc parabolique à rotules, continu sur deux ouvertures ». (Calculation of the continuous pivoted parabolic arch on two openings).

tem and will be independent of the loads. This constitutes the enormous advantage of the present method over that of Castigliano, which necessitates a fresh start being made with the calculation for each fresh case of loading.

Owing to the symmetry we can push the transformations of the equations still further so as to obtain finally two systems, one of which has two equations and the other has only one. The calculation of determinants of the third order being easy, especially with the use of a calculating machine, we will retain our equations (3), remarking in passing that the determinants of the second order of the form $a.b - c.d.$ are rapidly obtained, since, if we manipulate the machine so as to obtain $a.b.$ and then in the opposite way for $c.d.$, we obtain $a.b - c.d.$

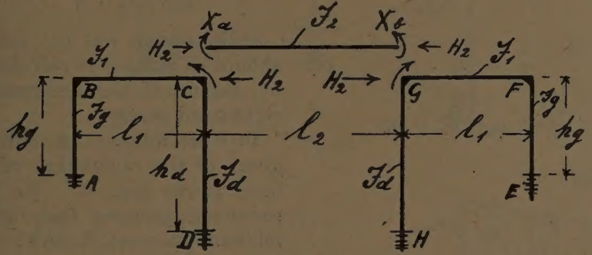

Fig. 1.

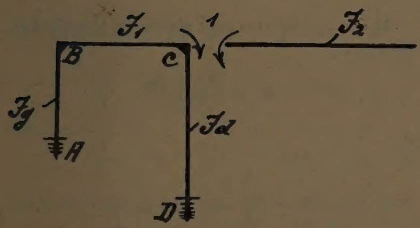

Fig. 2.

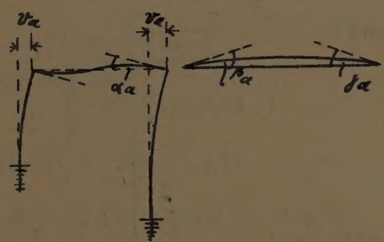

Fig. 3.

The state of load $X_a = -1$ is shown in figure 2. The moment $X_a = -1$, applied at the point C, will produce in the gantry moments M_A^a, M_B^a, M_C^a and M_D^a. According to the well-known formulæ we write for the different deformations shown in figure 3:

$$\left.\begin{aligned} EI_1\alpha_a &= \frac{l_1}{6}(M_B^a + 2M_C^a) \\ EI_2\beta_a &= \frac{l_2}{6} \quad 2 \end{aligned}\right\} \qquad (6)$$

All the deformations are multiplied by the same coefficient, for example EI_1. We shall therefore have

$$EI_1\beta_a = \frac{l_2}{3} \cdot \frac{I_1}{I_2}$$

and with:

$$\varphi_1 = \frac{l_2}{l_1} \cdot \frac{I_1}{I_2} \quad \ldots\ldots \quad (7)$$

$$EI_1\beta_a = \frac{l_1\varphi_1}{3}$$

whence, with :

$$\delta_{aa} = \alpha_a + \beta_a$$

$$EI_1\delta_{aa} = \frac{l_1}{6}(M_B^a + 2M_C^a) + \frac{l_1 \cdot \varphi_1}{3} \quad (8)$$

The points B and C will therefore be displaced the same distance v_a to the right. We find that :

$$EI_g v_a = \frac{h_g^2}{6}(2M_A^a + M_B^a)$$

and with :

$$\frac{h_g}{l_1} \cdot \frac{I_1}{I_g} = \varphi_g \quad \ldots\ldots \quad (9)$$

$$EI_1 v_a = \frac{h_g l_1}{6} \cdot \varphi_g (2M_A^a + M_B^a)$$

We shall have :

$$1 \cdot \delta_{ac} = \frac{1}{h_d} \cdot v_a$$

$$EI_1 \cdot \delta_{ac} = \frac{h_g}{h_d} \cdot \frac{l_1}{6} \cdot \varphi_g (2M_A^a + M_B^a) \quad (10)$$

and :

$$\delta_{ab} = \gamma_a$$

$$EI_2\delta_{ab} = \frac{l_2}{6}$$

$$EI_1\delta_{ab} = \frac{l_1\varphi_1}{6} \quad \ldots\ldots \quad (11)$$

Owing to the symmetry of the system, we find that :

$$\delta_{bb} = \delta_{aa} \quad \ldots\ldots \quad (12)$$

$$\delta_{bc} = \delta_{ac} \quad \ldots\ldots \quad (13)$$

The horizontal live loads $H_2 = -\frac{1}{h_d}$ according to formula (2) applied at the points C and G of the two gantries, owing to $X_c = -1$, will produce in the points A, B, C, D and E, F, G, H, moments $M_A^c = M_E^c$, $M_B^c = M_F^c$, $M_C^c = M_G^c$ and $M_D^c = M_H^c$ which will deform the gantries somewhat after the fashion shown in figure 3. Assuming by analogy α_c, β_c, γ_c and v_c the values α, β, γ and v resulting from $X_c = -1^c$, we write :

$$\alpha_c = \delta_{ca} = \delta_{cb}; \quad \beta_c = \gamma_c = 0$$

$$\frac{2v_c}{1 \cdot h_d} = \delta_{cc}$$

and

$$EI_1\delta_{ca} = EI_1\delta_{cb} = \frac{l_1}{6}(M_B^c + 2M_C^c) \quad (14)$$

$$EI_1\delta_{cc} = \frac{2h_g l_1 \varphi_g}{h_d \cdot 6}(2M_A^c + M_B^c). \quad . \quad (15)$$

If the system was not symmetrical we should be obliged to calculate δ_{bb} and δ_{bc} by means of the deformations of the right-hand gantry.

In what follows, an indication will be given of the calculation of the doubly-fixed gantry (fig. 4). We introduce as redundant stresses the right-hand and left-hand moments X_1 and X_2 of the girder and :

$$X_3 = H \cdot h_o \quad \ldots\ldots \quad (16)$$

H being the normal stress in the girder. We put :

$$\left.\begin{array}{l} h_o = \dfrac{h_g + h_d}{2} \\ \dfrac{h_g}{l_1} \cdot \dfrac{I_1}{I_g} = \varphi_g; \quad \dfrac{h_d}{l_1} \cdot \dfrac{I_1}{I_d} = \varphi_d \end{array}\right\} \quad . \quad . \quad (17)$$

and operate with the deformations multiplied by EI_1. The state of load $X_c = -1$ is to be seen in figure 5. The surface of the moments is a rectangle of the height 1 for the left-hand upright and a triangle of the same height for the girder. For the right-hand upright it is zero. The deformations are easily calculated. They can be indicated at once, the surfaces of the moments being of regular shape. We have :

$$EI_1\gamma_1 = \frac{l_1}{6}$$

$$EI_1\beta_1 = \frac{l_1}{3}$$

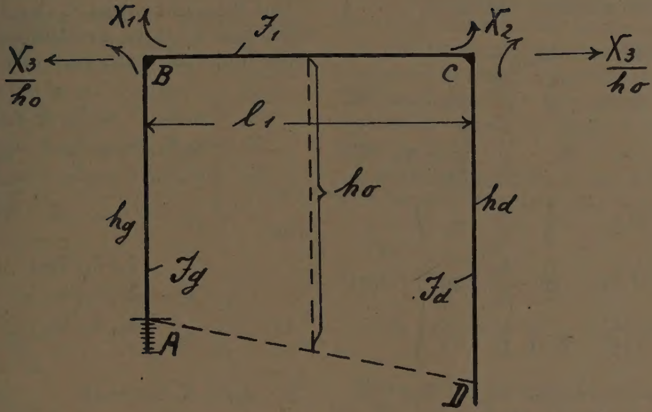

Fig. 4.

$$\mathrm{EI}_1 \cdot \alpha_1 = l_1 \varphi_g \quad . \; . \; . \; . \quad (18)$$

$$\mathrm{EI}_1 u_1 = \frac{h_g l_1 \varphi_g}{2} \quad . \; . \; . \quad (19)$$

$$\delta_{11} = \alpha_1 + \beta_1, \; \delta_{12} = \gamma_1, \; \delta_{13} = \frac{1}{h_o} \cdot u_1$$

$$\left.\begin{aligned} \mathrm{EI}_1 \delta_{11} &= \frac{l_1}{3}(1 + 3\varphi_g) \\ \mathrm{EI}_1 \delta_{12} &= \frac{l_1}{6} \\ \mathrm{EI}_1 \delta_{13} &= \frac{l_1 \cdot h_g}{2 \cdot h_o} \cdot \varphi_g \end{aligned}\right\} \quad (20)$$

By analogy we obtain :

$$\left.\begin{aligned} \mathrm{EI}_1 \delta_{22} &= \frac{l_1}{3}(1 + 3\varphi_d) \\ \mathrm{EI}_1 \delta_{21} &= \frac{l_1}{6} \\ \mathrm{EI}_1 \delta_{23} &= \frac{l_1}{2} \cdot \frac{h_d}{h_o} \cdot \varphi_d \end{aligned}\right\} \quad (21)$$

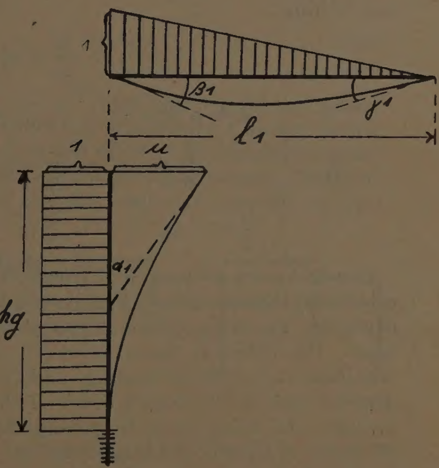

Fig. 5.

For $X_3 = -1$ we shall have to apply two horizontal forces equal to $\frac{1}{h_o}$ at the top ends of the uprights. The surfaces of the moments will be triangles having the height $-\frac{h_g}{h_o}$ and $-\frac{h_d}{h_o}$ for the uprights. The surface for the girder will be zero. We assume α_3. β_3, γ_3 and u_3

to be the deformations due to $X_3 = -1$ and put:

$$EI_1\gamma_3 = EI_1\beta_3 = 0.$$

$$EI_1\alpha_3 = \frac{l_1}{2} \cdot \frac{h_g}{h_o} \cdot \varphi_g \quad . . . (22)$$

$$EI_1 \cdot u_3 = h_g \cdot \frac{l_1}{3} \cdot \frac{h_g}{h_o} \cdot \varphi_g \quad (23)$$

and:

$$\left.\begin{aligned} EI_1\delta_{31} &= EI_1\delta_{13} = \frac{l_1}{2} \cdot \frac{h_g}{h_o} \cdot \varphi_g \\ EI_1\delta_{32} &= EI_1\delta_{23} = \frac{l_1}{2} \cdot \frac{h_d}{h_o} \cdot \varphi_d \\ EI_1\delta_{33} &= \frac{l_1}{3}\left(\frac{h_g^2}{h_o^2} \cdot \varphi_g + \frac{h_d}{h_o^2} \cdot \varphi_d\right) \end{aligned}\right\} \quad (24)$$

Our three unknowns X_1, X_2, and X_3 are submitted to three equations similar to those indicated under (4). We find:

$$\left.\begin{aligned} X_1 &= \alpha_{11}\delta_{01} + \alpha_{12}\delta_{02} + \alpha_{13}\delta_{03} \\ X_2 &= \alpha_{21}\delta_{01} + \alpha_{22}\delta_{02} + \alpha_{23}\delta_{03} \\ X_3 &= \alpha_{31}\delta_{01} + \alpha_{32}\delta_{02} + \alpha_{33}\delta_{03} \end{aligned}\right\} \quad (25)$$

with:

$$\Delta = \begin{vmatrix} \delta_{11} & \delta_{12} & \delta_{13} \\ \delta_{21} & \delta_{22} & \delta_{23} \\ \delta_{31} & \delta_{32} & \delta_{33} \end{vmatrix} \quad . . . (26)$$

$$\left.\begin{aligned} \Delta \cdot \alpha_{11} &= \delta_{22} \cdot \delta_{33} - \delta_{23}^2; & \Delta \cdot \alpha_{22} &= \delta_{11}\delta_{33} - \delta_{13}^2 \\ \Delta \cdot \alpha_{12} &= -(\delta_{12}\delta_{33} - \delta_{23} \cdot \delta_{31}); & \Delta \cdot \alpha_{23} &= -(\delta_{11}\delta_{23} - \delta_{12}\delta_{13}) \\ \Delta \cdot \alpha_{13} &= \delta_{12}\delta_{23} - \delta_{22}\delta_{13}; & \Delta \cdot \alpha_{33} &= \delta_{11}\delta_{22} - \delta_{12}^2 \end{aligned}\right\} \quad . . \quad (27)$$

and writing:

$$\frac{h_g}{h_o} = v_g\ ; \quad \frac{h_d}{h_o} = v_d \quad . . . . \quad (28)$$

$$\Delta = \begin{vmatrix} \frac{l_1}{3}(1 + 3\varphi_g) & \frac{l_1}{6} & \frac{l_1}{2} v_g\varphi_g \\ \frac{l_1}{6} & \frac{l_1}{3}(1 + 3\varphi_d) & \frac{l_1}{2} v_d\varphi_d \\ \frac{l_1}{2} v_g \cdot \varphi_g & \frac{l_1}{2} v_d \cdot \varphi_d & \frac{l_1}{3}(v_g^2 \cdot \varphi_g + v_d^2 \cdot \varphi_d) \end{vmatrix} \quad . . . (29)$$

Our first piece of work will consist in calculating the determinant Δ, numerically of course. The calculation is effected three times, the columns being reversed to eliminate errors in calculation, and the determinants of the second order of the formulæ (27) being found in passing. All the terms of Δ are of the first power for l_1. It would not have been so if we had chosen $X_3 = H$ instead of $X_3 = H.\ h_0$. We should have found terms containing h_g and h_d to the first and second power, which would have made the terms vary considerably among themselves and would have increased the magnitude of the calculation.

Once the coefficients α_{11}, α_{12} ... have been obtained, X_1, X_2 and X_3 are calculated according to the formula (25). Let us assum that it is a question of finding the influence of a load P stressing the girder at the distance X from the point B. The deflection of the girder at this spot as a result of $X_1 = -1$ will be equal to δ_{01}. This deformation will result from a triangular surface of moment (fig. 5). It will be the same for δ_{02} with this difference only that the point of the right-angled triangle will be on the left hand side instead of on the right hand side, and δ_{03} will be zero, the girder not being submitted to any bending due to $X_3 =$

— 1. Formulæ are to be found for the deformations of girders for different surfaces of moment (rectangle, triangle, parabola, etc.) in almost any text book. Employing the terms selected by Müller-Breslau, we put :

$$\left.\begin{aligned} EI_1 \cdot \delta_{01} &= P\frac{l_1^2}{6} \cdot \omega_r' \\ EI_1 \cdot \delta_{02} &= P\frac{l_1^2}{6} \cdot \omega_r \end{aligned}\right\} \quad (30)$$

with

$$\left.\begin{aligned} \omega_r &= \frac{x}{l_1} - \frac{x^3}{l_1^3} \\ \omega_r &= \frac{l_1 - x}{l_1} - \frac{(l_1 - x)^3}{l_1^3} \end{aligned}\right\} \quad (31)$$

hence

$$X_1 = \frac{Pl^2}{6}(\alpha_{11} \cdot \omega_r' + \alpha_{12}\,\omega_r) \quad (32)$$

This calculation is rapidly effected with the aid of tables for the values ω_r and ω_r'.

It will be shown in what follows how to proceed in order to find the moments of the frame due to a moment $M = -1$, applied as shown in figure 2 (condition $X_a = -1$).

According to figure 5 and by analogy with formulæ (18) and (19), we have :

$$\left.\begin{aligned} EI_1 \cdot \delta_{01} &= 0 \\ EI_1 \cdot \delta_{02} &= -l_1\varphi_d \\ EI_1 \cdot \delta_{03} &= -\frac{l_1}{2} \cdot v_d \cdot \varphi_d \end{aligned}\right\} \quad (33)$$

These values furnish us with X_1, X_2 and X_3 according to formulæ (25). We have :

$$\left.\begin{aligned} M_B^a &= X_1\,; & M_C^a &= X_2 \\ M_A^a &= X_1 + X_3 \cdot \frac{h_g}{h_o}\,; & M_D^a &= X_2 + X_3 \cdot \frac{h_d}{h_o} \end{aligned}\right\} \quad \ldots\ldots \quad (34)$$

As has already been emphasised, our method of calculation may be applied to any triple-span bridge, whether symmetrical or otherwise. There is only one step therefore from this calculation to that of a bridge with numerous spans. In figure 6 is represented a bridge having 11 openings which is 33 times hyperstatic.

We select a principal system composed of 6 gantries connected together by girders rigidly fixed at the two ends. This system can be calculated by means of 6 groups of equations having 3 unknowns. There are, therefore, only 15 redundant stresses to calculate. $X_r = -1$ will deform the gantry of the fifth opening and the girder of the sixth, to which are applied the stresses X_{r-2} to X_{r+2}, *i. e* 5 altogether. Real values will be found therefore for the deformations δ_{rr-2} to δ_{rr+2} while for the others there will be :

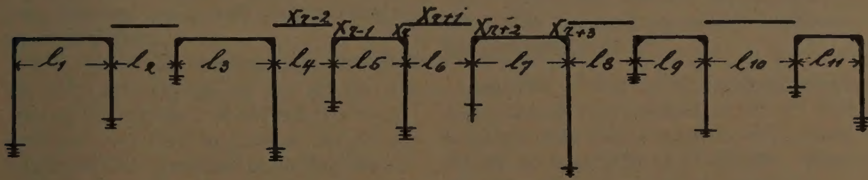

Fig. 6.

$$\delta_{r\,r-3} = \delta_{r\,r-4} = \ldots\ldots\ \delta_{r\,r+3} = \delta_{r+4} = \delta_{r\,r-m} = \delta_{r\,r+m} = 0 \quad \ldots\ldots \quad (35)$$

The r^{th} equation will only contain therefore 5 unknowns.

X_{r+1} being the normal stress for the girder for the sixth opening, $X_{r+1} = -1$ will deform in addition to this girder the gantries of the fifth and seventh openings, to which are applied the stresses X_{r-2} to X_{r+4}. For this case we shall have :

$$\left.\begin{aligned} \delta_{r+1\ r-3} = \delta_{r+1\ r-4} = \ldots\ldots \delta_{r+1\ r-m} = 0 \\ \delta_{r+1\ r+5} = \delta_{r+1\ r+6} = \ldots\ldots \delta_{r+1\ r+m} = 0 \end{aligned}\right\} \quad \ldots\ldots\ldots \quad (36)$$

The $r + 1^{th}$ equation will only contain therefore 7 unknowns.

In fine, we shall have reduced a system of 33 equations to one of 15, 5 of which having 7 unknowns, while the 10 others do not contain more than 5, and that without making any restrictions as to the moments of inertia of the different parts, although the system may be quite unsymmetrical.

In actual practice, such a system would never be carried out owing to the unfavourable influence of expansion. We have, however, considered it important to show that the calculation is quite practicable, even for a large number of openings. The effect of temperature is, moreover, fairly large even for a triple-span girder.

[625. 172 & 625. 174]

REPORT No. 1

(Belgium, France, Italy, Portugal, Spain and their Colonies)

ON THE QUESTION OF RECENT IMPROVEMENTS IN PERMANENT WAY TOOLS AND IN THE SCIENTIFIC ORGANISATION OF MAINTENANCE WORK (SUBJECT IV FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION) [1],

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Figs. 1 to 16, pp. 4 to 35.

INTRODUCTION

First of all we wish to express our regret and disappointment that a large number of the Administrations consulted have neither replied nor sent the information called for by our questionnaire.

The result is that in view of the importance of some of this information, the report we are asked to make will be incomplete and not as well authenticated as we could wish.

Out of 86 administrations consulted 36 only have replied, or say 42 %. By basing the replies and abstentions on kilometres, we find that since the 86 administrations consulted cover 113 064 km. and that those who replied represent 93 080, we get a percentage of 82.32.

The classification by country of the administrations who have replied is as follows :

Portugal. — Of 5 administrations consulted only one, with 1 379 km. of line replied. The railway system of the country containing 3 939 km., we find that valued kilometrically, this reply represents 35 %.

Italy. — Of 21 administrations consulted, one only replied, or say 4.8 %. But this having a system of 16 493 km. out of 20 165 km. over the whole country, the result obtained represents a kilometric percentage of 81.

Belgium. — Out of 10 administrations consulted, 5 only replied or 50 %, but kilometrically this is equal to 96 %, since out of an aggregate of 11 004 km., those who have replied represent 10 500 km.

Spain. — 10 administrations consulted, 6 replies, equals 60 %. Kilometrically, this represents 90 %, as the 6 administrations who have replied account for 9 773 km. out of a total of 10 955 for the 10 consulted.

(1) Translated from the French.

France. — Of 40 administrations consulted, covering 67 001 km., 24 representing 56 031 km. replied, *i. e.* the replies equal 60 % numerically and 83.63 % kilometrically.

However, the foregoing must not be taken as strictly correct, since some of the replies received gave no information, but simply stated that they could not furnish useful data. There were 5 of these, one Belgian, one Spanish, and three French. Consequently, the sources of information reduced to 31 administrations represent only 92 147 km. or 81.5 % of the kilometric extent represented by the administrations we consulted.

We have collated in a condensed form the replies of the administrations and followed them with concise comments on the data supplied in the order of each of the subjects comprised in the questionnaire reproduced below; and in tables 1 to 5 we have concentrated by nationality all the data supplied by these administrations.

Belgian administrations.

Table 1 gives the chief characteristics of the replies of the Belgian administrations to the different clauses of the questionnaire in so easy and comprehensible a form that the conclusions may be seen at a glance.

We will now review, point by point, and question by question, all the replies received.

FIRST PART.

Recent improvement in the mechanical appliances for maintenance of the permanent way.

Question 1. — *Have you introduced or improved of late years the mechanical appliances for maintaining the permanent way; and if so, how long ago is it since you adopted them ?*

Do you employ mechanical appliances for the following operations :

a) *Preparation of the roadbed;*

b) *Loading, transporting and unloading ballast;*

c) *Loading and unloading rails and sleepers;*

d) *Spreading and packing the ballast;*

e) *Unloading and placing in position fully assembled lengths of track;*

f) *Transport of materials over the road;*

g) *Drilling and adzing the sleepers;*

h) *Setting the sleepers;*

i) *Laying the rails;*

j) *Driving the coach screws of chairs or sole-plates into the sleepers;*

k) *Screwing up the bolts in the joints or other parts of the track;*

l) *Levelling the ballast;*

m) *Aligning, levelling and packing the track;*

n) *Weeding and cleaning the ballast either over the whole width, or only beyond the sleepers;*

o) *Straightening, cutting and drilling rails;*

p) *Do you utilise special vehicles for carrying permanent way material ?*

q) *For what other purpose ?*

As regards the different operations which constitute the maintenance of permanent way and which are listed in the questionnaire, the Belgian National Railway Company has adopted since 1896 mechanical means on some lines for handling the rails (c), transport of material along

the road (f), for driving the screws (g), tightening up the bolts (g), cutting and drilling the rails (o). The Congo Railway Company has used tipping wagons, or wagons with drop bottom doors and drop sides for transporting soil or ballast.

In the first place it may be noted that these mechanical methods are only used in a few instances, whereas they might be applied in a very interesting manner to the other operations mentioned in the questionnaire. It is desirable that they should be adopted, or at least tried in the future, and as soon as possible.

The results obtained have been satisfactory; in fact they could not be otherwise, and the first result to which one aspires in every modern industry has been the diminution (the suppression being impossible) of manual labour, which is always costly, and is frequently accompanied by disputes and difficulties due to the many social questions which arise.

Let us now examine in detail each of these applications.

Question 2. — *If using such equipment, please describe those in use, explained by designs, drawings, or photographs, and any other facts which you consider useful for a perfect understanding.*

Question 3. — *Please state purchase price, cost of installation, and running expenses.*

Question 4. — *What are the economic advantages resulting from the use of these appliances, taking into account wages, auxiliary tools, lubricating oils and grease, interest and sinking fund for cost of apparatus, etc.?*

How many men are necessary to work the apparatus ?

Question 5. — *Please state the minimum length of road after which the use of mechanical appliances would be of value or effect economies.*

Question 6. — *If the economical advantages are few, what are the other advantages which have led to the introduction of this equipment, for instance, the time required to carry out the operations by one or the other method under average or normal conditions ?*

Question 7. — *When using such appliances on the line, what is the source of power utilised ?*

Can it be used while the road in question is in service ?

Is it transportable without blocking the traffic ?

What radius of action has it without shifting the source of power ?

Figure 1 shows the apparatus employed for handling the rails, particularly for loading the supplies on the wagons.

It enables the carrying out of certain operations with 6 rails at a time, without employing mechanical power.

Its cost is not high, 10 000 Belgian francs, nor the working cost per day, 140 Belgian francs. As indicated, it shows a saving of 50 % over manual work. The number of workmen is reduced to four, and its use is justified when rails are to be handled for renewing or relaying 5 km. (3.1 miles) of line.

For driving the screw bolts, the use of electric sets fitted with apparatus for driving and tightening them is strongly recommended. Each equipment is composed of the set described and of two tools, also like those indicated. This equipment represents an outlay of 70 000 Belgian francs and a saving of 53 % by employing only two men instead of about 30.

Fig. 1. — Belgian National Railway Company. — Gantries for handling rails.

The use of such an arrangement is recommended for work over not less than 10 km. (6.2 miles) of line.

The use of special spanners of the Robel type (fig. 2) is also recommended for inserting and tightening up fishplate bolts. This apparatus is well known, cheap — only costing 45 Gold-marks — and shows a saving of 50 %. It is worked by one man. Its use is to be recommended, and it is suitable for any length of track laid.

Finally, without specifying any type, the use is recommended of apparatus for cutting and drilling the rails, and especially for drilling in point layouts within stations, which often require rails of special length to be prepared.

This method of drilling the ends effects a saving of 80 %.

For transporting material along the track the Belgian National Railway Company considers trolleys very useful in repair work, and also trains of tip wagons which are run over the line as ordinary trains.

The first cost is 50 000 Belgian francs for the trolley, and 8 000 fr. for each tip wagon.

The average cost of transport per ton over a distance of 5 km. (which is the minimum distance for which this method would be useful) is 2.44 fr. and shows the very appreciable saving of 30 %, to say nothing of the saving of time and reduction in accidents.

The Congo Railway Company which uses for the transport of stone ballast side tipping wagons or double bottom door wagons with drop sides, does not give any details of the saving effected by their use; but it is safe to assume it will be similar, *i. e.* from 30 % to 50 % over manual labour only.

Commenting on this first part, we would say that the references are very few and the experiences too recent for this report to be regarded as conclusive.

SECOND PART.

Scientific organisation of permanent way maintenance.

QUESTION 1. — *What is the organisation for the maintenance of the permanent way on your system ?*

A. *As regards staff :*

a) *Evenly distributed over the lines;*

b) *Concentrated in specially selected areas;*

c) *Staff specially engaged in the maintenance of signalling works, tunnels, bridges, etc.*

B. *Inspection and protection of the road :*

a) *At special works, tunnels, bridges, etc.;*

b) *Level crossings;*

c) *Over the whole stretch of line.*

The three Belgian administrations who have replied have their maintenance staff divided up into gangs, uniformly distributed along the lines.

Only the first, the Belgian National Railway Company has, in addition, independent gangs in the stations and keeps a specialised staff for signal maintenance. It has not, like the two others, any particular staff for special works, such as tunnels, bridges, etc.

As will be seen, the principle of uniformity of distribution of the staff predominates, centring in important stations in the case of those administrations who

Fig. 2. — Robel spanner for fishplate bolts.

have a large number of big and impor tant stations.

Question 2. — *Have you made any innovations during recent years looking towards economy in maintenance of the permanent way?*

The first-named administration considers useful (or desirable) the adoption of integral or partial renewal, having given up maintenance by making good defects found by walking over the line.

Question 3. — *What is the latest equipment of your chief roads; weight and length of rails; type of joints; number and kind of sleepers; method of fixing the rails to the sleepers; quality of ballast?*

No special comment is necessary, the replies being given in the table.

Question 4. — *What is the average length of road maintained by a gang on the main lines? How many men are there in a gang, including the foreman, and as the case may be, the assistant foreman?*

The gangs are organised for the maintenance of 4 to 6 km. (2.5 to 3.7 miles) of double or 7 to 8 km. (4.3 to 5 miles) of single track, each workman having 2 km. (1.2 miles) to look after. They consist usually of 4 to 6 men. In special cases, such as at big stations, there may be 10.

On the Belgian Light Railway Company's lines, where the speed of the trains

is low, each man looks after 3 km. (1.9 miles) and the gangs consist of 4 to 5 men plus the foreman.

QUESTION 5. — *Do you use formulæ (or tables) to determine the number of men required for the maintenance of a certain length of road (single track or several tracks)? If so, what are these formulæ?*

How do you show in these formulæ the length of sidings and the number of points, equal to a certain length of main line?

Only the Belgian National Railway Company uses tabulated formulæ as ready reckoners for determining the make-up of gangs, taking into consideration the following circumstances, in order to fix the number according to the number of trains:

Junctions;
Points;
Crossovers;
Cuttings;
Radii (curves);
Gradients;
Tunnels, etc.

This system may be very scientific and convenient; but in reality it may give rise to many complications.

QUESTION 6. — *Is the number of men in a gang the same for winter and summer; or are your gangs made up of a minimum number of men, employees of the Company, and added to in the summer by temporary hands?*

Considering the length of the winter and the difficulty of keeping the gangs fully employed, it is as well to reduce to the minimum the size of the regular gangs, and augment it during the summer.

We consider the system rather dangerous, as it is precisely during the winter that the line requires the most careful watching, with more regular maintenance.

QUESTION 7. — *What other work have the gangs to do, like cleaning out ditches, cutting hedges, etc.; or is this work contracted out?*

The answer is in the affirmative.

QUESTION 8. — *For permanent way maintenance, is your system maintained by doing work found necessary by inspection or by general periodical relaying? If the latter, what is the interval between general renewals?*

Both systems are employed. General renewal by the first two administrations; in the second, constant supervision and repair is maintained both summer and winter: this latter system is applied by the last of the administrations.

QUESTION 9. — *In the case of maintenance by general renewal, is it carried out by the ordinary gangs, or by special gangs relaying the whole of the line?*

Gangs are augmented in summer by the first administration and normal in summer in the two latter.

QUESTION 10. — *What technical processes are employed for:*

a) *The preparation of material before using;*

b) *Care of material in service, stating average life of different materials;*

c) *Slewing the track;*

d) *Packing and aligning;*

e) *Cleaning and weeding the ballast.*

Attention is chiefly given to the sleepers, which are impregnated and dressed

before laying, whenever the kind of wood justifies it; and holes from which screws have been withdrawn are filled with a tarred plug of very hard wood.

It will be very interesting to learn what the first of these administrations will decide to do to close up the cracks which occur in all hard wood sleepers, whether by means of bolts put through from side to side, or by bands. We consider this method the most suitable, even if costly.

Question 11. — *Do you carry out certain work under contract by your own staff, or do you offer a bonus for completion within a certain fixed period?*

If so, what is the bonus, calculated on the wages of the men?

How is the work checked in such cases?

Does not this method of doing work under contract or for a bonus have a bad effect on the quality of the work done? What is the cost per year per kilometre of single track?

For the reasons suggested it is feared that work under such conditions is unsatisfactory; and it is for that reason alone that bonuses have not been established for permanent way maintenance.

Question 12. — *What are the working hours of ordinary platelayers, etc.? Are they fixed by law? If so, is any distinction made between ordinary, extraordinary or urgent work?*

Question 13. — *If working hours are regulated, do they count from the time when the workman arrives at the place where the work should begin, or from the moment when he reaches the railway company's property at the point nearest to his home?*

An eight-hour day is observed, counting from the moment of arrival at the actual spot.

Question 14. — *Do you use auto cars to take men to their work? Under what conditions do they run?*

The Belgian National Railway Company uses trolleys, which run like trains, to take men to their work.

Question 15. — *Are artisans (carpenters, painters, masons, etc.) and signal and telegraph men provided with means of transport, either bicycles or motors? If the first, do the bicycles belong to the Railway Company or to the employees who receive an allowance for their upkeep?*

This administration does not provide either bicycles or motors, exception being made in the case of certain electricians who have to cover long distances; but in lieu allows the workmen to use their own bicycles or motors.

Question 16. — *What measures are taken to increase the life of materials according to the importance of the traffic?*

See remarks on question 10.

Question 17. — *Graphs of the progress of all the works mentioned, showing their results from the point of view of economy.*

1. *Have you determined and fixed by graphs from exact observation of the work done on your lines the normal period, standardised, requisite for each partial operation, as well as for all heavy work to be done on the track, e. g.*

A. — *For handling material, as:*

a) *Loading or unloading per ton of rails;*

b) *Loading or unloading per cubic metre of ballast, etc.*

B. — *Maintenance work, properly so called, as :*

a) *Renewing of rails per metre;*

b) *Packing per sleeper, with different kinds of ballast;*

c) *Aligning per metre of road, in plan and in elevation;*

d) *Renewing a sleeper in the track (in a station);*

e) *Renewing ballast, per cubic metre;*

f) *Weeding track, per metre of road;*

g) *General inspection of track, per metre;*

h) *Renewing track, etc., per metre.*

2. *How have you kept account, in determining the standardised normal operations, of loss of time due to traffic or any other cause ?*

Negative reply. This is very regrettable, as we consider it very desirable to record the results on graphs, which are always very conclusive.

Question 18. — *Technical education of men entrusted with the direction and carrying out of these works.*

Method of selection.

Are they required to have an official professional degree ?

Does the administration give facilities for the education of this staff ?

If so, give details about the organisation of the schools.

Generally, the custom is to leave the choice of workmen free, but to have recourse to examination and competition for foremen of gangs or districts.

The reply of the Belgian National Light Railway Company is very definite as regards the appointment of these two classes of officials, for not only is their technical capacity taken into consideration, but also their ability to handle men.

None of these administrations possesses training schools for these officials.

Review of the previous remarks.

1. Mechanical methods are not very general for maintaining permanent way, and the details given are recent, and apply to trials over a short period. In view of these circumstances, and notwithstanding the methodical certainty of the results given, they cannot be considered as definite.

2. The organisation of gangs and their uniform distribution down the line is common to all administrations. It is only modified by the Belgian National Railway Company which, in the important stations, maintains larger and independent gangs.

On some sections of the line the composition of the standard gang is altered as a function of various factors according to different constants.

3. The composition of the gangs varies according to the administration, but they are usually so formed that each man has to look after 2 km. (1.2 miles) of single track, though some administrations make it 3 km. (1.9 miles).

4. It is as well to reduce the gangs in the winter and strengthen them in the summer.

5. The method of relaying in sections predominates over that of maintenance as found necessary.

6. No facts are given regarding the annual cost of maintenance per kilometre of road.

7. The usual working day is eight hours — from time of reaching to time of leaving the actual work.

8. The conveyance of workmen to the job by trolleys treated as trains as regards operating is beginning to be looked into.

9. Technical instruction has not yet been directly provided by the administrations.

Spanish administrations.

Table 2 summarises the replies of the Spanish administrations. All, with complete uniformity, relate to similar principles and systems. Consequently, their study and the commentary thereon are easy and rapid; and we have followed a similar system to that employed for studying the replies of the Belgian administrations.

FIRST PART.

Recent improvement in the mechanical appliances for maintenance of the permanent way.

QUESTION 1. — *Have you introduced or improved of late years the mechanical appliances for maintaining the permanent way; and if so, how long ago is it since you adopted them ?*

Do you employ mechanical appliances for the following operations :

a) *Preparation of the roadbed;*

b) *Loading, transporting and unloading ballast;*

c) *Loading and unloading rails and sleepers;*

d) *Spreading and packing the ballast;*

e) *Unloading and placing in position fully assembled lengths of track;*

f) *Transport of materials over the road;*

g) *Drilling and adzing the sleepers;*

h) *Setting the sleepers;*

i) *Laying the rails;*

j) *Driving the coach screws of chairs or sole-plates into the sleepers;*

k) *Screwing up the bolts in the joints or other parts of the track;*

l) *Levelling the ballast;*

m) *Aligning, levelling and packing the track;*

n) *Weeding and cleaning the ballast either over the whole width, or only beyond the sleepers;*

o) *Straightening, cutting and drilling rails;*

p) *Do you utilise special vehicles for carrying permanent way material ?*

q) *For what other purpose ?*

QUESTION 2.— *If using such equipments, please describe those in use, explained by designs, drawings, or photographs, and any other facts which you consider useful for a perfect understanding.*

QUESTION 3. — *Please state purchase price, cost of installation, and running expenses.*

QUESTION 4. — *What are the economic advantages resulting from the use of these appliances, taking into account wages, auxiliary tools, lubricating oils and grease, interest and sinking fund for cost of apparatus, etc.?*

How many men are necessary to work the apparatus?

QUESTION 5. — *Please state the minimum length of road after which the use of mechanical appliances would be of value or effect economies.*

QUESTION 6. — *If the economical advantages are few, what are the other advantages which have led to the introduction of this equipment, for instance, the*

time required to carry out the operations by one or the other method under average or normal conditions?

QUESTION 7. — *When using such appliances on the line, what is the source of power utilised.*

Can it be used while the road in question is in service?

Is it transportable without blocking the traffic?

What radius of action has it without shifting the source of power?

The replies of the Spanish administrations are negative in character and show that mechanical methods have not been adopted for the maintenance, properly so called, of the permanent way, although in certain reports both the Madrid to Saragossa and Alicante Railway and the North of Spain, state that they have used, when relaying the line, apparatus of the Collet type for packing, dressing the sleepers and inserting the screws. Although this work may in some respects be considered as belonging to maintenance of permanent way, its importance is due to other features, and without doubt it should be included among improvements and new works. It is for this reason that in the table these methods are not given as being in use.

The results attained when renewing the line have been favourable as regards time and quality of work, as well as from the economical point of view, for they show a saving of from 25 to 30 % approximately.

In its reply the North of Spain not only states that it does not employ mechanical apparatus, but also that it would be of very little use, since it appears to require trained workmen, difficult to find, and who moreover require high wages.

We do not share this opinion, for the tools generally used are simple and can be used by any man after very short tuition. Consequently, the wages asked need not be high.

And even supposing there might be an increase of some wages, these tools enable a large number of working days to be saved.

For this reason, it seems desirable that the tools in question be given a trial, in order to ascertain their value in service.

SECOND PART.

QUESTION 1. — *What is the organisation for the maintenance of the permanent way on your system?*

A. — *As regards staff:*

a) *Evenly distributed over the lines;*

b) *Concentrated in specially selected areas;*

c) *Staff specially engaged in the maintenance of signalling works, tunnels, bridges, etc.*

B. — *Inspection and protection of the road:*

a) *At special works, tunnels, bridges, etc.;*

b) *Level crossings;*

c) *Over the whole stretch of line.*

The organisation of gangs of a uniform type is common to all administrations, except that the North of Spain Railway has established a uniform distribution throughout the length of the line, giving each gang a longer or shorter section according to the conditions of the line, layout, etc.

This procedure, although favourable, in so far as it suits the means to the needs, we cannot entirely endorse, as we believe it is better to give to each gang the same

relative length of line, and to strengthen any particular one, if special circumstances call for heavier work.

Both the Madrid-Saragossa-Alicante and the North of Spain Railways have special gangs of varying composition, allocated to and concentrated at the most important stations solely in order to keep them in good repair. There are also gangs for the upkeep of tunnels, bridges, interlocking, etc.

The three other companies who have replied have not expressed themselves sufficiently clearly about this, for us, most interesting system.

As regards supervision, the five companies agree as to the establishment of a special system of keepers for level crossings, where the protection is subject to provisions of a legal nature, which are certain to be modified, with a tendency towards reduction and simplification.

For tunnels and bridges the North of Spain and the Madrid-Saragossa-Alicante Railways have special supervisors; and for the general supervision of the line both companies have special police, which generally carry out their duties during the night.

The other three companies entrust this work to the ordinary maintenance men.

Question 2. — *Have you made any innovations during recent years looking towards economy in maintenance of the permanent way?*

In 1912, the North of Spain Company substituted for the method common in Spain of maintenance « as found needed » that of a thorough overhaul bi-annually, with which they say they are satisfied, although there may not be any advantage economically.

The Madrid-Saragossa-Alicante Railways, which adhere to maintenance « as found needed », has begun on certain specified sections to try packing with the shovel which should give good results, but as these trials only go back four years, no definite or economic information can yet be given.

Question 3. — *What is the latest equipment of your chief roads; weight and length of rails; type of joints; number and kind of sleepers; method of fixing the rails to the sleepers; quality of ballast?*

The different data is given in the corresponding column of the table, and consequently any comment is useless.

Question 4. — *What is the average length of road maintained by a gang on the main lines? How many men are in a gang, including the foreman, and if there are such, the assistant and sub-assistant foreman?*

The composition of the gangs varies, as well as the length of road each has to maintain, but there is no unifirmity as to the average length per man.

The North of Spain Company uses gangs of 7 men; the Andalusian and the Madrid-Saragossa-Alicante Railways 5 only.

The Andalusian Railways carry out their maintenance trials over 6 km. (3.7 miles) per gang; the Central of Aragon over 12 km. (7.5 miles), with an average of 1 km. (0.62 miles) per man for the North of Spain and 2 (1.24 miles) for the Central Aragon and the Madrid-Saragossa-Alicante Railways.

It is therefore impossible to pass judgment based solely on these facts, as one would have to know other circumstances to be able to appreciate the position.

If all the comparisons are based on single line, it is perfectly possible to as-

sign 2 km. (1.24 miles) to each man. In our opinion, and generally speaking, not less than 2 km. should be given to each man.

Question 5. — *Do you use formulæ (or tables) to determine the number of men required for the maintenance of a certain length of road (single track or several tracks?) If so, what are these formulæ?*

How do you show in these formulæ the length of sidings and the number of points, equal to a certain length of main line?

The North Company — very logically in our opinion — has fixed standards by which they determine the value of the different works, and the difficulties the men encounter, according to the length of road; but this line of action is applied in our opinion wrongly, instead of strengthening the gangs.

Question 6. — *Is the number of men in a gang the same for winter and summer; or are your gangs made up of a minimum number of men, employees of the Company, and added to in the summer by temporary hands?*

The fixed annual number of men is constant with an addition when needed of auxiliary workmen.

Question 7. — *What other work have the gangs to do, like cleaning out ditches, cutting hedges, etc.; or is this work contracted out?*

The same gangs do all this work on every Company.

Question 8. — *For permanent way maintenance, is your system maintained by doing work found necessary by inspection or by general periodical relaying? If the latter, what is the interval between general renewals?*

Every Company uses the method « as found necessary », except the North, which, as already stated, has since 1912 followed the system of thorough overhaul bi-annually, with which it is very satisfied, without, however, giving comparative results between the two systems.

Question 9. — *In the case of maintenance by general renewal, is it carried out by the ordinary gangs, or by special gangs relaying the whole for the line?*

The same ordinary gangs.

Question 10. — *What technical processes are employed for:*

a) *The preparation of material before using;*

b) *Care of material in service, stating average life of different materials;*

c) *Slewing the track;*

d) *Packing and aligning;*

e) *Cleaning and weeding the ballast.*

Only preparing the sleepers and cleaning the ballast.

Question 11. — *Do you carry out certain work under contract by your own staff, or do you offer a bonus for completion within a certain fixed period?*

If so, what is the bonus, calculated on the wages of the men.

How is the work checked in such cases?

Does not this method of doing work under contract or for a bonus have a bad effect on the quality of the work done?

What is the cost per year per kilometre of single track?

Generally the reply seems negative, for only the Andalusian Company states that

it sometimes employs a system of piece work, but never pays a bonus.

Question 12. — *What are the working hours of ordinary platelayers, etc.? Are they fixed by law? If so, is any distinction made between ordinary, extraordinary or urgent work?*

Question 13. — *If working hours are regulated, do they count from the time when the workman arrives at the place where the work should begin, or from the moment when he reaches the Railway Company's property at the point nearest to his home?*

Generally an established day of eight hours, commencing with the arrival of the men at the job and ending when they leave.

Question 14. — *Do you use auto cars to take men to their work? Under what conditions do they run?*

Question 15. — *Are artisans (carpenters, painters, masons, etc.) and signal and telegraph men provided with means of transport, either bicycles or motors? If the first, do the bicycles belong to the Railway Company or to the employees who receive an allowance for their upkeep?*

Question 16. — *What measures are taken to increase the life of materials according to the importance of the traffic?*

All Companies replied in the negative.

Question 17. — *Graphs of the progress of all the works mentioned, showing their results from the point of view of economy.*

1. — *Have you determined and fixed by graphs from exact observation of the work done on your lines, the normal period, standardised requisite for each partial operation, as well as for all heavy work to be done on the track, e. g.*

A. — *For handling material, as:*

a) *Loading or unloading per ton of rails;*

b) *Loading or unloading per cubic metre of ballast, etc.*

B. — *Maintenance work, properly so called, as:*

a) *Renewing of rails per metre;*

b) *Packing per sleeper, with different kinds of ballast;*

c) *Aligning per metre of road, in plan and in elevation;*

d) *Renewing a sleeper* in situ;

e) *Renewing ballast, per cubic metre;*

f) *Weeding track, per metre of road;*

g) *General inspection of track, per metre;*

h) *Renewing track, etc., per metre.*

2. — *How have you kept account, in determining the standardised normal operations, of loss of time due to traffic or any other cause?*

Only the North Company, which on account of the system of thorough overhaul it uses, keeps charts of the work, without however indicating the economic results.

Question 18. — *Technical education of men entrusted with the direction and carrying out of these works.*

Method of selection.

Are they required to have an official professional degree?

Does the administration give facilities for the education of this staff?

If so, give details about the organisation of the schools.

Of all the companies who have sent replies, the Central Aragon alone does not

give any details. Two others state their staff is nominated by selection.

The Madrid-Saragossa-Alicante and the North state that up to now, applicants for district foreman have to pass an examination before a duly constituted Commission. But the Madrid-Saragossa-Alicante, in view of the mediocre results obtained lately from the officials who have gone in for the examination without having the requisite technical knowledge, although their practical knowledge and the difficulty of studying owing to living at a distance from the instruction centre, has been taken into account, is considering the establishment of professional schools of the particular grade for the theoretical and practical instruction of its officials who wish to profit by their teaching in order to obtain the post of district foreman on giving proof of their capacity.

Summary of the previous remarks.

1. Mechanical methods for maintenance, properly so called, of the permanent way have not been employed.

2. Uniform distribution of gangs for the most part is common to all the companies, but exception is made of some who, in conformity with formulæ and variable factors reduce the number of kilometres assigned to each gang according to the importance and difficulties of the line. The most important companies keep permanent gangs for the large stations.

3. The composition of the gang varies according to the administration, but mostly the strength is based on 2 km. (1.24 mile) of single track per man. In certain cases the length is reduced to 1 km. (0.62 mile).

4. Gangs remain at same normal strength throughout the year, but are added to by casual labour if there is extra work to be done.

5. The system « as found necessary » prevails over that of periodical inspection throughout.

6. The annual cost of maintenance per kilometre of single track is not given.

7. An eight-hour day is observed, counting from arrival at the job up to the moment of leaving. No travelling allowance is made, whatever may be the distance from the job.

8. No company has provided mechanical transport for the men to their work.

9. Although up to now technical instruction has not been provided directly by the administrations, a school will be started shortly by the Madrid-Saragossa-Alicante Company.

French administrations.

Table 3 gives the 22 replies of the French administrations and is specially interesting because it represents almost the whole of the trunk lines.

Below we transcribe these replies, keeping to the different paragraphs for purposes of comparison.

FIRST PART.

Recent improvement in the mechanical appliances for maintenance of the permanent way.

QUESTION 1. — *Have you introduced or improved of late years the mechanical appliances for maintaining the permanent way; and if so, how long ago is it since you adopted them ?*

Do you employ mechanical appliances for the following operations :

a) *Preparation of the roadbed;*

b) *Loading, transporting and unloading ballast;*

c) *Loading and unloading rails and sleepers;*

d) *Spreading and packing the ballast;*

e) *Unloading and placing in position fully assembled lengths of track;*

f) *Transport of materials over the road;*

g) *Drilling and adzing the sleepers;*

h) *Setting the sleepers;*

i) *Laying the rails;*

j) *Driving the coach screws of chairs or sole-plates into the sleepers;*

k) *Screwing up the bolts in the joints or other parts of the track;*

l) *Levelling the ballast;*

m) *Aligning, levelling and packing the track;*

n) *Weeding and cleaning the ballast either over the whole width, or only beyond the sleepers;*

o) *Straightening, cutting and drilling rails;*

p) *Do you utilise special vehicles for carrying permanent way material?*

q) *For what other purpose ?*

QUESTION 2. — *If using such equipment, please describe those in use, explained by designs, drawings, or photographs, and any other facts which you consider useful for a perfect understanding.*

QUESTION 3. — *Please state purchase prise cost, of installation, and running expenses.*

QUESTION 4. — *What are the economic advantages resulting from the use of these appliances, taking into account wages, auxiliary tools, lubricating oils and grease, interest and sinking fund for cost of apparatus, etc.?*

How many men are necessary to work the apparatus ?

QUESTION 5. — *Please state the minimum length of road after which the use of mechanical appliances would be of value or effect economies.*

QUESTION 6. — *If the economical advantages are few, what are the other advantages which have led to the introduction of this equipment, for instance, the time required to carry out the operations by one or the other method under average or normal conditions ?*

QUESTION 7. — *When using such appliances on the line, what is the source of power utilised ?*

Can it be used while the road in question is in service ?

Is it transportable without blocking the traffic ?

What radius of action has it without shifting the source of power ?

The use of mechanical methods and tools is very general for maintaining the permanent way, particularly on the trunk lines, although all are unanimous in stating that on account of the short time these methods have been used, they cannot supply conclusive opinions.

The State Railways, the Est and the Paris, Lyons & Mediterranean (P. L. M.) are those who have used most mechanical means. These methods are stated below in the order of their largest application.

First of all, transport on the line is by means of trolleys of adequate power, taking into account the profile of the line and the load to be hauled by the trains,

Fig. 3. — Tamper. Power used by eight sets : 4.4 kw.
Output 150 sleepers an hour.

and generally composed of tipping wagons, which is a type very generally in use and of varying dimensions.

We find that this very effective system is used by the State Railways, Est, Midi, Paris-Orleans, Paris, Lyons & Mediterranean, and the Tunisian Railways. The trains are signalled in the same way as regular trains.

However, the administrations consulted do not say anything as to the minimum distance over which this method of transport is economical.

Next in order come the methods used for destroying weeds on the line. Generally they are hand weeded by the ordinary gangs, but two other different methods have been employed. One, a mechanical, has shown nearly always poor results. The other, although chemical, may be also considered as mechanical owing to the use of special trains for its application.

Simple mechanical methods have been used by the State, Est, Midi and Paris, Lyons & Mediterranean Railways. The three other administrations used chemical means.

Fig. 4. — Train of hopper or tip wagons hauled by motor tractor. One of the train formations.

Usually these trains (figs. 8 and 10) are made up of a motor trolley, a tank wagon for the liquid (usually chlorate of sodium or « occisol »), a pump wagon, a travelling workshop, and another wagon with a stock of salt.

Although the reply is not decisive on the subject of economy, the State Railways report a coefficient of 72 %.

Now come the tamping tools usually of the Collet type (fig. 3) for the sleepers, operated by petrol motor and used by the State Railways and also by the « Société des Transports en commun de la Région parisienne ».

The State and the Tunisian Railways drill the sleepers in the shops where they are impregnated and dressed, and not on the spot.

The ends of worn rails are sawn and redrilled, for use then on secondary lines, making points and crossings etc. The Est and the « Société des Transports en Commun de la Région Parisienne » do this in travelling workshops (fig. 7).

For spreading soil and ballast the State and the Est Railways use flat cars with bottom doors and drop sides.

For tightening bolts, the State Rail-

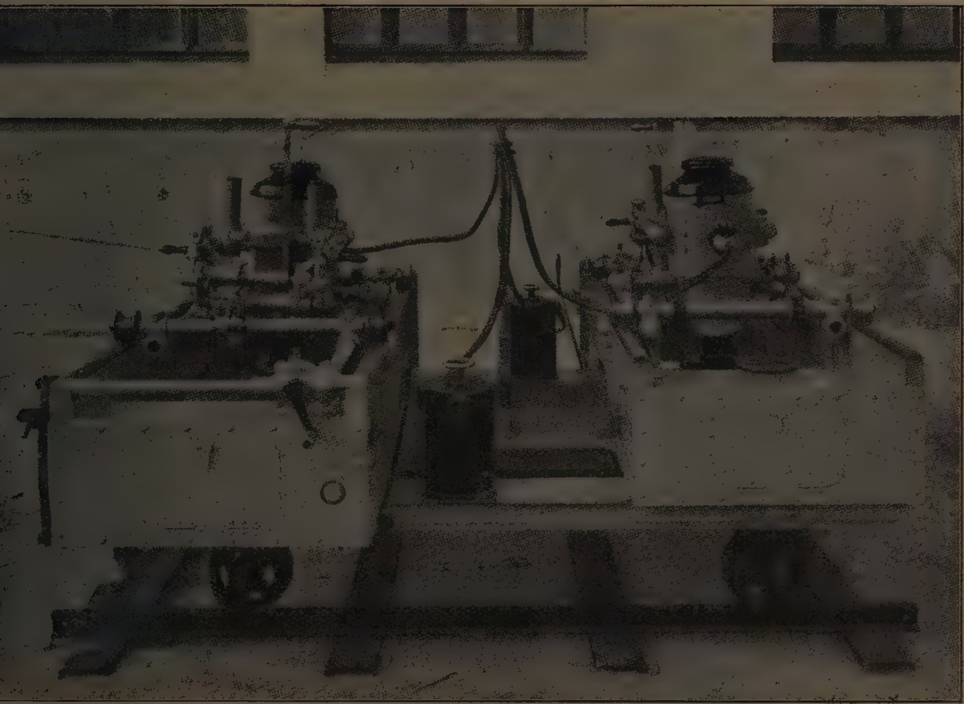

Fig. 5. — Collet notching and drilling machine.
Average power taken : 6 kw. — Output : 125 sleepers an hour.

ways use spanners driven by small petrol motors.

For unloading rails, the Est uses special wagons of great length, with ends arranged to allow 3 or 4 rails at a time to be unloaded by means of small trolleys and pulleys (fig. 6).

It is to be regretted that owing to the short time these methods have been employed, there are no conclusive economical facts available.

SECOND PART.

Scientific organisation of permanent way maintenance...

QUESTION 1. — *What is the organisation for the maintenance of the permanent way on your system ?*

A. — *As regards staff :*

a) *Evenly distributed over the lines;*

b) *Concentrated in specially selected areas;*

c) *Staff specially engaged in the maintenance of signalling works, tunnels, bridges, etc.*

B. — *Inspection and protection of the road :*

a) *At special works, tunnels, bridges, etc.;*

Fig. 6.

b) *Level crossings;*
c) *Over the whole stretch of line.*

The organisation set up for the composition and distribution of gangs may be divided into four main classes, as follows :

a) Spread out over the line and of uniform composition;
b) Uniform distribution; composition variable;
c) Distribution variable; composition uniform;
d) Distribution and composition variable.

Usually the French administrations come under paragraphs (*a*), (*c*) or (*d*), their choice being decided by the state of the road, the number of stations, halts, junctions, etc.

Based on importance and length of line, the chief administrations adhere to classification (*c*), amongst whom are the State, Paris-Orleans, Paris, Lyons & Mediterranean, the Paris Girdle and the Algerian and the Tunisian Railways.

Those who adopt classification (*d*) are the Est, Midi, Alsace-Lorraine, P. L. M. (Algerian Lines), the Dahomey, the Damascus to Hamah and the Smyrna to Cassaba Railways.

In the first group (*a*) are the five least important administrations.

From the foregoing it may be deduced

Fig. 7.

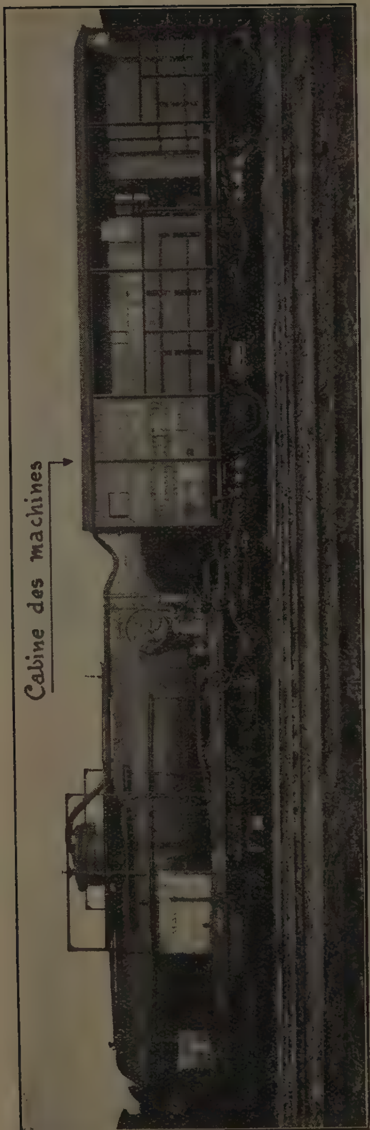

Fig. 8. — Paris, Lyons & Mediterranean System. — Chemical weed killing plant. General view.

that the chief companies, in order to attain the greatest degree of flexibility, have not hesitated to go to the utmost limits of variety in the composition of their gangs. Whilst possessing the advantages indicated, this variety gives rise to difficulties of organisation and accounting at headquarters.

In the same paragraph there is a very interesting point relating to the formation of independent gangs for maintenance of permanent way by concentrating workers for certain important works.

Similarly, special gangs are formed for the maintenance of plant, work of a special kind, tunnels, bridges, lockings, signals, etc., etc.

The formation of special gangs is quite usual. These mainly look after the lines in the large stations and are composed of the permanent staff according to the importance of the work. Administrations which have adopted the system are the State, Alsace-Lorraine, Midi, Paris-Orleans and the Dahomey Railways.

In those companies which have not made use of these arrangements, it is the ordinary gangs, specially allocated, who look after these installations.

For the upkeep of metal bridges, the State, Est, the Algerian and the Smyrna to Cassaba Railways have special gangs.

On the State and the Paris Girdle Railways, there is a new method of upkeep, *viz.* by contractors who specialise in that class of work. It is quite admissible, although seeing the importance of such special work, it seems to us it should be carried out by the Railway Company.

As regards the watching of bridges, works under construction, and special installations, level crossings and the track in general, unanimity exists as to level crossings. On the other hand there is a tendency to attach special watchmen

Fig. 9.

to the regular maintenance gangs, generally at night.

This opinion is not held by the following companies :

Midi, Tarn Departmental, Dahomey, and the Société des Transports en commun de la Région parisienne.

This is not to say that these companies do not have watchmen, but the work is done by the maintenance gangs, without however having to provide for night watching.

Question 2. — *Have you made any innovations during recent years looking towards economy in maintenance of the permanent way?*

Amongst the operations of a technical character already developed, that of shovel tamping is in very general use. It is a process which lightens materially the laying of the track, and shows very great saving in maintenance. It has been adopted with good results, according to information supplied, by the Paris Girdle, the Est and the Paris, Lyons & Mediterranean Railways.

The State mentions, as a method from which much is hoped, the formation of a superior body entrusted with the inspection and control of the permanent way and its maintenance. This body seems to us unnecessary, and it will be well to await the result.

Finally the Paris, Lyons & Mediterranean states it hopes to get good results

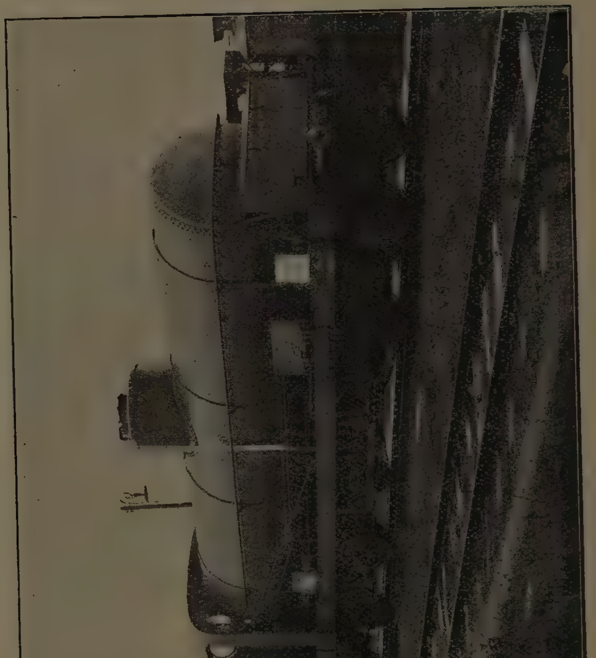

Fig. 10.

Fig. 11. — Paris, Lyons & Mediterranean System. — Motor tractor trains. Off-loading sleepers.

Fig. 12.

Fig. 13.

Fig. 14.

Fig. 15.

Fig. 16.

by reducing the lengths allotted to the gangs.

On the other hand the Tarn Departmental Company asserts having obtained the same result by increasing the length and strengthening the gangs.

Consequently, it will be as well to await further information.

QUESTION 3. — *What is the latest equipment of your chief roads; weight and length of rails; type of joints; number and kind of sleepers; method of fixing the rails to the sleepers; quality of ballast ?*

Any remarks are superfluous, as the table shows the kind of track used by each company.

A good number of them mention standard types of rail.

QUESTION 4. — *What is the average length of road maintained by a gang on the main lines ? How many men are in a gang, including the foreman, and if there are such, the assistant and sub-assistant foreman ?*

Although the composition of the gangs is governed by such circumstances as profile and service, as well as traffic cost of labour and weather conditions, there are no observations beyond those comprised in the replies received, an examination of which shows that the result which lends itself best to a comparison is that of kilometres maintained per man, which gives a scale ranging from 3 km. to 0.75 km. (1.86 to 0.465 mile) per man. Below we give the number of kilometres assigned to each man by the different companies :

Midi and Tarn : 3 km. (1.93 miles).
Sud-Ouest : 2.05 km. (1.27 miles).
Smyrna-Cassaba : 2.25 km.(1.39 miles).
Midi, single track Orleans, Tunis Railways and Dahomey : 2 km. (1.24 miles).
Paris, Lyons & Mediterranean, Algerian and Smyrna-Cassaba: 1.60 km.(0.99 mile).
State, Alsace-Lorraine, Est and Algerian : 1.35 to 1.2 km. (0.84 to 0.74 mile).

For the secondary lines 1 km. (0.62 mile) on the State and the Paris-Orleans and 0.75 km. (0.465 mile) in Indo-China.

The size of the gang varies from 3 to 10 men, and the number of kilometres to be maintained between 5 and 15 (3.1 to 9.3 miles).

Taking an average of all the administrations by length of road and size of gangs in each, we get 1.95 km. (1.21 mile) per man, a figure which we consider acceptable.

QUESTION 5. — *Do you use formulæ (or tables) to determine the number of men required for the maintenance of a certain length of road (single track or several tracks)? If so, what are these formulæ?*

How do you show in these formulæ the length of sidings and the number of points, equal to a certain length of main line ?

In order to decide what should be the number of men per gang, when the system adopted is that of variability of the gangs, or a reduction in the length allotted to each, one accepts the method practised by the many companies who do not employ scientific or fixed methods, and a few do it according to output per man.

On the other hand, other companies use methods derived from the study of comparisons and observations with coefficients, or from more or less empirical formulæ, but always with a certain base.

In this second group we find a method which is very simple and is applied by

the State. It consists in fixing a certain length of main or secondary road per man, and calculating the number of workmen by multiplying this length with its coefficient.

Another method is employed by the Est, Alsace-Lorraine and Paris, Lyons & Mediterranean Railways, *viz.* applying variable coefficients according to the conditions of each job, the number of points and crossings, length ,etc. Below we state the practice of each of these companies :

Alsace-Lorraine. — 1 man per 1.5 km. (0.93 mile) of single track=1 man per 1 km. (0.62 mile) of double track=1 man per 0.6 km. (0.37 mile) of triple track = 1 man per 0.25 km. (0.155 mile) of quadruple track=1 man per 60 points, taking single points as one and double crossovers as two.

Paris, Lyons & Mediterranean. — 1 man per 2 km. (1.24 mile) of single main line track = 1 man per 0.8 (0.50 mile) of double main line track, each pair of points being equivalent to 0.1 km. (0.06 mile) of single main line track.

Lastly, the Anzin Company adopts the following formula :

$$N = 1.3\ L + 2.5\ P + 0.5\ h.;$$

wherein :

N = Number of men;
P = Number of stations and halts;
L = Length of main line;
h = Length of track in stations.

In view of the small number of formulæ and coefficients employed, they cannot be accepted as a pattern.

Nevertheless, the convenience of following this method must be recognised, since it is the only reasonable and scientific one.

Question 6. — *Is the number of men in a gang the same for winter and summer; or are your gangs made up of a minimum number of men, employees of the company, and added to in the summer by temporary hands ?*

Generally, it may be stated that in France and her Colonies, the gangs are composed of regular hands and are augmented only by auxiliary help when circumstances require it.

Question 7. — *What other work have the gangs to do, like cleaning out ditches cutting hedges, etc.; or is this work contracted out ?*

The regular hands look after these supplementary jobs.

Question 8. — *For permanent way maintenance, is your system maintained by doing work found necessary by inspection or by general periodical relaying ? If the latter, what is the interval between general renewals ?*

Question 9. — *In the case of maintenance by general renewal, is it carried out by the ordinary gangs, or by special gangs relaying the whole of the line ?*

Most of the administrations and particularly of the trunk lines with heavy and frequent traffic adopt the method of general overhaul at periods varying according to the one or the other, or even according to the importance of their lines.

It must be recognised that a strong opinion exists in favour of this method of work, it being declared to give entire satisfaction, over the abandoned method of repairs as found needed. It is to be regretted that it has not been stated whether the advantages secured represent better work or a saving in labour and material.

Below we give the administrations which use this method and the time which elapses between two inspections.

Every two years: State, Alsace-Lorraine, Orleans.

Every three years : State, Alsace-Lorraine, Midi, Orleans, Paris, Lyons & Mediterranean, Tunisian.

Every four years : State, Paris Girdle, Midi, Orleans and Tunisian, and without fixing a period : Est, Paris, Lyons & Mediterranean, Société des Transports en commun de la Région parisienne, Algeria, State, Tunisian.

The same companies appear in different periods, because they are concerned with lines of different importance.

Contrary to the foregoing, the Bouches-du-Rhône, Dahomey, Algerian and Smyrna-Cassaba Railways follows the method of repairs as needed, *i. e.* the least important amongst the companies consulted.

The two systems are used, as under trial, by the Paris, Lyons & Mediterranean, the Algerian, and the Damascus-Hamah Railways.

From this survey, it would seem that it is better to employ the system of thorough overhaul by the regular maintenance gangs.

QUESTION 10. — *What technical processes are employed for :*

a) *The preparation of material before using;*

b) *Care of material in service, stating average life of different materials;*

c) *Slewing the track;*

d) *Packing and aligning;*

e) *Cleaning and weeding the ballast.*

Mention is made only of the dressing and impregnation of sleepers at special yards, and the tarring of metal work to be placed in the tunnels.

QUESTION 11. — *Do you carry out certain work under contract by our own staff, or do you offer a bonus for completion within a certain fixed period ?*

If so, what is the bonus, calculated on the wages of the men.

How is the work checked in such cases?

Does not this method of doing work under contract or for a bonus have a bad effect on the quality of the work done ?

What is the cost per year per kilometre of single track ?

None of the administrations consulted works at agreed prices; only the Est Railways pays a premium for speed and perfection in the general overhaul.

The fact that this method is not used, although in harmony with modern practice, makes one fear that the work may be done carelessly whereas it ought to be done very carefully, and that it imposes too great a responsibility; in spite of close supervision, it is really impossible to get work as well done as if it were carried out under contract.

QUESTION 12. — *What are the working hours of ordinary platelayers, etc.?*

Are they fixed by law ? If so, is any distinction made between ordinary, extraordinary or urgent work?

QUESTION 13. — *If working hours are regulated, do they count from the time when the workman arrives at the place where the work should begin, or from the moment when he reaches the Railway Company's property at the point nearest to his home ?*

All French administrations are subject to the legal eight-hour day, which is reckoned from the time of arrival at the job to the moment of leaving. Nevertheless, when a man has to travel more than 5 km. (3.1 miles), the day is reduced by a quar-

ter of an hour per kilometre to be travelled in excess of 5 km.

Overtime is allowed in urgent cases, at 50 % increase in wages.

In the Colonial administrations these regulations are not in force, the day varying between 9 to 10 hours.

QUESTION 14. — *Do you use auto-cars to take men to their work? Under what conditions do they run?*

QUESTION 15. — *Are artisans (carpenters, painters, masons, etc.) and signal and telegraph men provided with means of transport, either bicycles or motors? If the first, do the bicycles belong to the Railway Company or to the employees who receive an allowance for their upkeep?*

All the administrations reply in the negative. Only the Bouches-du-Rhône say they make an allowance of 10 fr. per month for maintenance and repairs to men with bicycles, it being understood that they will use them in their work.

QUESTION 16. — *What measures are taken to increase the life of materials according to the importance of the traffic?*

All say « None ».

QUESTION 17. — *Graphs of the progress of all the works mentioned, showing their results from the point of view of economy.*

1. — *Have you determined and fixed by graphs from exact observation of the work done on your lines, the normal period, standardised, requisite for each partial operation, as well as for all heavy work to be done on the track, e. g.*

A. — *For handling material, as:*

a) *Loading or unloading per ton of rails;*

b) *Loading or unloading per cubic metre of ballast, etc.*

B. — *Maintenance work, properly so called, as:*

a) *Renewing of rails per metre;*

b) *Packing per sleeper, with different kinds of ballast;*

c) *Aligning per metre of road, in plan and in elevation;*

d) *Renewing a sleeper* in situ;

e) *Renewing ballast, per cubic metre;*

f) *Weeding track, per metre of road;*

g) *General inspection of track, per metre;*

h) *Renewing track, etc., per metre.*

2. — *How have you kept account, in determining the standardised normal operations, of loss of time due to traffic or any other cause?*

Some, but very few, administrations recommend the use of graphs for following up the progress of work, particularly when the method of general overhaul is adopted. None of them, however, show the economic results obtained by these graphs, which was the reason of the question set.

QUESTION 18. — *Technical education of men entrusted with the direction and carrying out of these works.*

Method of selection.

Are they required to have an official professional degree?

Does the administration give facilities for the education of this staff?

If so, give details about the organisation of these schools.

All the administrations consulted have replied that it would be advisable to establish the best suitable formulæ, recognising the importance of getting properly educated men, although they recognise

the difficulty of getting this education outside of the administrations who know exactly the capabilities and knowledge which their officials should have.

If central technical schools are used, they usually have the disadvantage of giving too general instruction, and, of course, have no practical teaching. If the instruction is entrusted to the initiative of the staff, it has been found that they do not provide themselves with the most suitable books, even if such exist.

It would be well to let them follow one of the two methods, and to complete the course by means of lectures given by superior officers, whilst giving facilities for the use of proper books.

The officials to whom these facts particularly apply are foremen of gangs and district foremen, in view of the importance of their positions in the operation of a modern railway.

We will now consider the principal solutions reported :

All are in accord with freedom of selection in engaging workmen, and each lays down a system which it believes to be the best for selecting its staff.

They employ selection after enquiry into the antecedents of candidates, who undergo an examination, the knowledge for which must have been acquired at their own cost.

This is the practice adopted by the Alsace-Lorraine, Midi, Orleans, Bouches-du-Rhône, Tarn, Anzin, Smyrna-Cassaba and Indo-China Railways.

This staff is then given facilities to take an official course of instruction, and when they have obtained a diploma, it is taken into consideration for the examinations of the Paris, Lyons & Mediterranean Company (France and Algeria), which refund them 50 % of what they have paid to acquire this knowledge.

The State Railways, Paris Girdle, Est, Algerian and Tunisian administrations supply gratuitously all educational requisites, and further lectures are given by the higher officials.

After this statement it will be easily understood that by employing one method or the other, the administrations consulted obtain well educated staff, thanks to the sacrifices they make to maintain these centres of instruction.

After what has been stated it may certainly be considered as very desirable to form technical schools entirely staffed by the companies themselves.

Summary of the foregoing remarks.

1. Mechanical means for maintenance of permanent way are numerous, and particularly for transporting material, weeding and tamping, and notching and drilling sleepers, but owing to the short time they have been in use, there are no sufficient comparative facts available to allow of an economic appreciation.

2. Maintenance by gangs is common to all administrations, but most of them have neither uniformity of distribution, nor of composition, although the practice of uniform composition and variable distribution predominates.

Nevertheless, it is possible to set up equivalent arrangements for those who prefer entire absence of uniformity of composition and distribution.

3. An interesting improvement is the use with greater economy and safety of packing with the shovel.

4. The composition of each gang and the length of road given to each are very variable.

Each comprises from 3 to 10 men, and the length of road varies between 5 and 15 km. (3.1 to 9.3 miles).

This averages out at an upkeep of 1.95 km. (1.21 mile) per man, although certain companies reduce this figure to 0.75 km. (0.465 mile).

5. There is a very large majority employing general overhaul at periods, more or less long, according to the importance of the lines and their traffic.

6. The general opinion is against confiding the maintenance to contractors, as also to giving it out to piece work, not even with a bonus.

7. The annual cost per kilometre of single track is not stated.

8. The eight-hour day is obligatory for all French Railways and in North Africa, it being understood that these cover time on the job, although workers are allowed a travelling time of 15 minutes per kilometre when the distance from their residence to the job exceeds 5 km. (3.1 miles).

9. No administration has arranged for the transport of its men to the job by mechanical means.

10. For recruiting the maintenance staff, there is complete agreement as to free selection of the lower grades, with examination and competition for the gang and district foremen.

It must, however, be noted that a good number of administrations are setting up, at their own cost, special schools for training these employees.

Italian administrations.

Only the State Railways, which have the greatest mileage in Italy, have replied. The answers are shown in table 4.

FIRST PART.

Recent improvements in the mechanical appliances for maintenance of the permanent way.

QUESTION 1. — *Have you introduced or improved of late years the mechanical appliances for maintaining the permanent way; and if so, how long ago is it since you adopted them?*

Do you employ mechanical appliances for the following operations:

a) *Preparation of the roadbed;*

b) *Loading, transporting and unloading ballast;*

c) *Loading and unloading rails and sleepers;*

d) *Spreading and packing the ballast;*

e) *Unloading and placing in position fully assembled lengths of track;*

f) *Transport of materials over the road;*

g) *Drilling and adzing the sleepers;*

h) *Setting the sleepers;*

i) *Laying the rails;*

j) *Driving the coach screws of chairs or sole-plates into the sleepers;*

k) *Screwing up the bolts in the joints or other parts of the track;*

l) *Levelling the ballast;*

m) *Aligning, levelling and packing the track;*

n) *Weeding and cleaning the ballast either over the whole width, or only beyond the sleepers;*

o) *Straightening, cutting and drilling rails;*

p) *Do you utilise special vehicles for carrying permanent way material?*

q) *For what other purpose?*

QUESTION 2. — *If using such equipment, please describe those in use, explained by designs, drawings, or photographs, and*

any other facts which you consider useful for a perfect understanding.

QUESTION 3. — *Please state purchase price, cost of installation, and running expenses.*

QUESTION 4. — *What are the economic advantages resulting from the use of these appliances, taking into account wages, auxiliary tools, lubricating oils and grease, interest and sinking fund for cost of apparatus, etc.*

How many men are necessary to work the apparatus ?

QUESTION 5. — *Please state the minimum length of road after which the use of mechanical appliances would be of value or effect economies.*

QUESTION 6. — *If the economical advantages are few, what are the other advantages which have led to the introduction of this equipment, for instance, the time required to carry out the operations by one or the other method under average or normal conditions ?*

QUESTION 7. — *When using such appliances on the line, what is the source of power utilised ?*

Can it be used while the road in question is in service ?

Is it transportable without blocking the traffic ?

What radius of action has it without shifting the source of power ?

The mechanical tools employed by this administration are numerous, and justify its reputation as progressive.

By employing petrol and compressed air motors, practical mobile power units have been formed for doing the work over each kilometre, bringing the current by cables laid parallel with the track with plug- in points at short distances apart. By means of these units tamping tools and spanners for inserting bolts and screws are driven.

The saving effected reaches 40 %; and further, there are very appreciable advantages in countries like Italy with malarial belts, because by its means a lot of work can be done in good weather, which by other means would take more time.

For transporting the material, trains of trolleys and hoppers are used, which run like ordinary trains.

Finally, but without giving details, the use of a machine for weeding is mentioned.

These facts are interesting, although nothing is said about any long experience with this work.

SECOND PART.

Scientific organisation of permanent maintenance.

QUESTION 1. — *What is the organisation for the maintenance of the permanent way on your system ?*

A. — *As regard staff :*

a) *Evenly distributed over the lines;*

b) *Concentrated in specially selected areas;*

c) *Staff specially engaged in the maintenance of signalling works, tunnels, bridges, etc.*

B. — *Inspection and protection of the road :*

a) *At special works, tunnels, bridges, etc.;*

b) *Level crossings;*

c) *Over the whole stretch of line.*

The practice is to have gangs not uniformly distributed along the line, nor

uniformly constituted, depending on the layout and equipment of the line.

For important stations, permanent and independent gangs are formed. For maintaining certain works like bridges, tunnels, interlockings, etc., neither special gangs nor officials are used, in spite of the good results which they have given on account of their specialisation.

Special watching is no longer practised at these points, except for level crossings, though that of the line in general is done by special watchmen appointed for this purpose alone.

QUESTION 2. — *Have you made any innovations during recent years looking towards economy in maintenance of the permanent way?*

For certain sections of line the maintenance is given to contractors, and with good results. However, it is recognised that most contractors have not the desired experience, and do not know this class of work, which requires careful supervision if the result is not to be uneconomical.

QUESTION 3. — *What is the latest equipment of your chief roads; weight and length of rails; type of joints; number and kind of sleepers; method of fixing the rails to the sleepers; quality of ballast?*

The different types of road and their characteristics are stated.

QUESTION 4. — *What is the average length of road maintained by a gang on the main lines? How many men are in a gang, including the foreman, and if there are such, the assistant and sub-assistant foreman?*

QUESTION 5. — *Do you use formulæ (or tables) to determine the number of men required for the maintenance of a certain length of road (single track or several tracks)? If so, what are these formulæ?*

How do you show in the formulæ the length of sidings and the number of points, equal to a certain length of main line?

The gangs are composed according to the layout of the road of from 10 to 17 men to maintain 5 to 7 km. (3.1 to 4.35 miles) of track, either single or double, in allotting each man from 2 to 2.4 km. (1.24 to 1.49 miles).

QUESTION 6. — *Is the number of men in a gang the same for winter and summer; or are your gangs made up of a minimum number of men, employees of the company, and added to in the summer by temporary hands?*

QUESTION 7. — *What other work have the gangs to do, like cleaning out ditches cutting hedges, etc.; or is this work contracted out?*

No special comment is called for on the replies to these questions.

QUESTION 8. — *For permanent way maintenance, is your system maintained by doing work found necessary by inspection or by general periodical relaying? If the latter, what is the interval between general renewals?*

QUESTION 9. — *In the case of maintenance by general renewal, is it carried out by the ordinary gangs, or by special gangs relaying the whole of the line?*

For several years the system of general overhaul at periods of 2, 3 or 4 years, according to the importance of the line, has been followed, and has given satisfaction.

Question 10. — *What technical processes are employed for :*

a) *the preparation of material before using;*

b) *care of material in service, stating average life of different materials;*

c) *slewing the track;*

d) *packing and aligning;*

e) *cleaning and weeding the ballast.*

The most interesting information is that which applies to the use of shovel packing as it is asserted that it effects a great saving of ballast, and gives great stability to the road.

Question 12. — *What are the working hours of ordinary platelayers, etc. Are they fixed by law ? If so, is any distinction made between ordinary, extraordinary or urgent work ?*

Question 13. — *If working hours are regulated, do they count from the time when the workmen arrives at the place where the work should begin, or from the moment when he reaches the Railway Company's property at the point nearest to his home ?*

It is stated that the statutory eight-hour day counts from arrival on the job to the time of leaving it.

Question 18. — *Technical education of men entrusted with the direction and carrying out of these works.*

Method of selection.

Are they required to have an official professional degree ?

Does the administration give facilities for the education of this staff ?

If so, give details about the organisation of the schools.

Admission into the service without examination is usual for the men, but candidates for employment as district or gang foreman undergo an examination. The administration supplies books to the candidates for their studies.

Summary of previous remarks.

1. Mechanical appliances for maintenance of permanent way are numerous. They give good results and show an appreciable saving.

2. Gangs are uniform neither in composition nor distribution, but depend on the layout of the road and existing equipment, though always based on certain coefficients. Certain of these gangs are employed only at important stations.

3. They are so composed that each man has to look after 2 to 2.4 km. (1.24 to 1.49 miles) according to whether the track is single or double.

4. Generally the size of the gang is fixed. However, when circumstances require exceptional work, it is given out to specialist contractors.

5. General overhaul is practised at varying periods according to the state of the line.

6. The average annual cost of upkeep per kilometre is not stated.

7. The statutory day is eight hours, actually on the job.

8. The administration does not provide transport to work.

9. Men are engaged by free selection. For employment as district or gang foreman, candidates undergo an examination after previous study for which the administration provides books.

Portuguese administrations.

Only one replied, the Portugal Railway Company, which does not represent the

most important railway system of Portugal, comprising only 35 % of the railways of the country. Table 5 gives the main details of this administration.

FIRST PART.

Recent improvements in the mechanical appliances for maintenance of the permanent way.

QUESTION 1. — *Have you introduced or improved of late years the mechanical appliances for maintaining the permanent way; and if so, how long ago is it since you adopted them ?*

Do you employ mechanical appliances for the following operations :

a) *Preparation of the roadbed;*

b) *Loading, transporting and unloading ballast;*

c) *Loading and unloading rails and sleepers;*

d) *Spreading and packing the ballast;*

e) *Unloading and placing in position fully assembled lengths of track;*

f) *Transport of materials over the road;*

g) *Drilling and adzing the sleepers;*

h) *Setting the sleepers;*

i) *Laying the rails;*

j) *Driving the coach screws of chairs or sole-plates into the sleepers;*

k) *Screwing up the bolts in the joints or other parts of the track;*

l) *Levelling the ballast;*

m) *Aligning, levelling and packing the track;*

n) *Weeding and cleaning the ballast either over the whole width, or only beyond the sleepers;*

o) *Straightening, cutting and drilling rails;*

p) *Do you utilise special vehicles for carrying permanent way material ?*

q) *For what other purpose ?*

QUESTION 2. — *If using such equipment, please describe those in use, explained by designs, drawings, or photographs, and any other facts which you consider useful for a perfect understanding.*

QUESTION 3. — *Please state purchase price, cost of installation, and running expenses.*

QUESTION 4. — *What are the economic advantages resulting from the use of these appliances, taking into account wages, auxiliary tools, lubricating oils and grease, interest and siking fund for cost of apparatus, etc.?*

How many men are necessary to work the apparatus?

QUESTION 5. — *Please state the minimum length of road after which the use of mechanical appliances would be of value or effect economies.*

QUESTION 6. — *If the economical advantages are few, what are the other advantages which have led to the introduction of this equipment, for instance, the time required to carry out the operations by one or the other method under average or normal conditions ?*

QUESTION 7. — *When using such appliances on the line, what is the source of power utilised ?*

Can it be used while the road in question is in service ?

Is it transportable without blocking the traffic ?

What radius of action has it without shifting the source of power ?

With regard to mechanical means for performing operations relating to track maintenance work, notching and drilling machines used in the impregnation yard are alone mentioned.

SECOND PART.

Scientific organisation of permanent way maintenance.

QUESTION 1. — *What is the organisation for the maintenance of the permanent way on your system?*

A. — *As regards staff:*

a) *Evenly distributed over the lines;*

b) *Concentrated in specially selected areas;*

c) *Staff specially engaged in the maintenance of signalling works, tunnels, bridges, etc.*

B. — *Inspection and protection of the road:*

a) *At special works, tunnels, bridges, etc.;*

b) *Level crossings;*

c) *Over the whole stretch of line.*

The organisation of the lower grade staff charged with the maintenance of permanent way, is the usual gang, but its composition varies although uniformly distributed according to the traffic, which is the factor which most influences its formation.

As has been already stated elsewhere, we consider this principle of varying the composition preferable to that of constantly altering the distribution.

The alteration in working of traffic would be acceptable, although other circumstances, and particularly that of the layout, might justify some variations.

The almost universal rule of forming special gangs for important stations is not observed, any more than for the upkeep of bridges and tunnels, nor signals, and interlockings.

Watching of tunnels, bridges, and level crossings is done by the same gangs who look after the road.

QUESTION 2. — *Have you made any innovations during recent years looking towards economy in maintenance of the permanent way?*

Although they have not been put to the tests, stone crashers for ballast, and quadricycles for transporting the men have been acquired.

QUESTION 3. — *What is the latest equipment of your chief roads; weight and length of rails; type of joints; number and kind of sleepers; method of fixing the rails to the sleepers; quality of ballast?*

All comment is useless.

QUESTION 4. — *What is the average length of road maintained by a gang on the main lines? How many men are in a gang, including the foreman, and if there are such, the assistant and sub-assistant foreman?*

QUESTION 5. — *Do you use formulæ (or tables) to determine the number of men required for the maintenance of a certain length of road (single track or several tracks)? If so, what are these formulæ?*

How do you show in these formulæ the length of sidings and the number of points, equal to a certain length of main line?

The length of road maintained varies according to whether it is double or single track. For this latter case 6 to 10 km. (3.7 to 6.2 miles) respectively with 6 and 7 workers, to which correspond 1.6 and 1.7 km. (0.99 and 1.05 miles) of single track according to circumstances.

Question 6. — *Is the number of men in a gang the same for winter and summer; or are your gangs made up of a minimum number of men, employees of the company, and added to in the summer by temporary hands ?*

Question 7. — *What other work have the gangs to do, like cleaning out ditches cutting hedges, etc.; or is this work contracted out ?*

All special remarks are useless.

Question 8. — *For permanent way maintenance, is your system maintained by doing work found necessary by inspection or by general periodical relaying ? If, the latter, what is the interval between general renewals ?*

Question 9. — *In the case of maintenance by general renewal, is it carried out by the ordinary gangs, or by special gangs relaying the whole of the line ?*

For several years general overhaul biannually has been practised. It gives satisfaction and is done by the ordinary gangs. However, no commentary has been made, nor any inference drawn between this method and that employed formerly.

Question 10. — *What technical processes are employed for :*

a) *the preparation of material before using;*

b) *care of material in service, stating average life of different materials;*

c) *slewing the track;*

d) *packing and aligning;*

e) *cleaning and weeding the ballast.*

No special remarks are called for.

Question 11. — *Do you carry out certain work under contract by your own staff, or do you offer a bonus for completion within a certain fixed period ?*

If so, what is the bonus, calculated on the wages of the men.

How is the work checked in such cases?

Does not this method of doing work under contract or for a bonus have a bad effect on the quality of the work done ?

What is the cost per year per kilometre of single track ?

Contrary to the general tendency, bonuses are awarded to the staff who direct the gangs, for quality and speed of work.

Question 12. — *What are the working hours of ordinary platelayers, etc.? Are they fixed by law ? If so, is any distinction made between ordinary, extraordinary or urgent work ?*

Question 13. — *If working hours are regulated, do they count from the time when the workmen arrives at the place where the work should begin, or from the moment when he reaches the Railway Company's property at the point nearest to his home ?*

Same information as given in the previous table.

Question 18. — *Technical education of men entrusted with the direction and carrying out of these works.*

Method of selection.

Are they required to have an official professional degree ?

Does the administration give facilities for the education of this staff ?

If so, give details about the organisation of the schools.

This report is interesting, as amongst the conditions laid down for promotion to the posts of gang and district foreman, it lays stress on that which requires the production of satisfactory certificates

from technical schools for the requisite specialised knowledge.

Summary of previous remarks.

1. The trials carried out are very limited, although good results have been obtained from the use of mechanical tools.

2. The practice exists of variable gangs uniformly distributed and without forming special ones for stations, regard being had to the conditions of traffic on the network of lines.

3. An average of 1.07 km. (1.05 miles) of single track is assigned obligatorily to each man : the same rule applies in the case of double track.

4. The strength of the gangs is fixed, and is augmented by casual labour when there is special work to be done.

5. For maintenance, general revision overhaul bi-annually is the rule.

6. The kilometric cost per year for upkeep of single track is not given.

7. The working day is usually eight hours, counting from arrival at the job to the time of leaving.

8. Up to now, means of transport have not been provided. As an experiment quadricycles have been purchased, but the results are still unknown.

9. The engagement of the ordinary staff is by nomination, but foremen of gangs and district must supply satisfactory certificates from technical schools.

GENERAL SUMMARY.

1. It is chiefly in France, Belgium and Italy that mechanical methods have been tried in permanent way maintenance, and according to information obtained the results have been satisfactory, showing an appreciable saving, reduction in labour, and perfection and speed in carrying out the work.

Particularly noteworthy are the tamping of sleepers, transport of material along the line, weeding and inserting the screws. Other, though less important, trials have been made with other kinds of work. Although the trial periods are recent, the administrations consulted have given tentative opinions that the savings effected are frequently round about 50 %.

2. The principles adopted for the formation of gangs, not only in the several countries consulted, but also in each of their administrations, are very numerous, for instance those of uniform and variable composition, in which provision is made for the division or variation of the length of road assigned to each gang, in order to adapt the means of work to the needs of the line entrusted to them.

However, none of the systems laid down can be considered as definitively preferable, in view of the reasons in favour of each. Nevertheless, in the interests of good accounting the greatest possible uniformity is recommended.

For the formation of those groups where uniformity does not exist, there are many bases for determining the number of men, taking into account the length they have to maintain. Either formulæ already established are employed, or the relative values of length of road, number of points, condition of the road, etc., are taken into consideration.

It is, however, well to call attention to the real difficulty which exists in determining these coefficients or equivalents on a general basis, in view of the numerous factors which govern them. In consequence it is very difficult to arrive at the greatest uniformity, however desirable it may be from every point of view.

Even in the administrations themselves its establishment is complex, since the condition of the road, works under con-

struction, tunnels, curves, cuttings and enbankments, offering greater or less ease of maintenance, enter into the calculation. Most of the administrations adopt the principle of permanent gangs employed exclusively in the maintenance of permanent way.

The formation of special gangs for certain work which requires special knowledge, and the upkeep of which ought to be independent from that of the road, as well as for that required for big constructional work, bridges, tunnels, metal roofs, interlockings, signals, electric and hydraulic apparatus, etc., is not as frequent as could be wished.

For the protection of the road, the general practice, particularly with the big administrations, is to have a certain number of men for protection and watching, independent from the ordinary maintenance.

The existence of special watchmen for the particular installations mentioned previously is not very common, although their establishment offers undoubted advantages. Naturally, it would mean employing independent gangs.

3. Owing to the difference in practice referred to already in the formation of gangs, their composition is very variable, both as to numbers and the length of road to be maintained. This length of single track assigned to each man, varies between an average of 0.75 to 3 km. (0.465 to 1.86 miles). However, the nearly mathematical average of all the administrations consulted comes out at 2 km. (1.24 mile) per man.

4. With the exception of the Belgian Administrations all the others keep to a standard size of gang throughout the year, with their officials. All, however, are reinforced whenever exigencies of work require it. The Belgian Administrations state that they reduce the size of the gangs during the winter, justifying this decision by the state of the weather, which, they say, does not allow them to profitably employ the whole of the available force.

Nearly all the administrations agree in having the work of cleaning ditches, etc., which is not contracted out, done by the ordinary maintenance gang.

5. Shovel packing is recommended by a good number of administrations, who state that it is the best means of obtaining a marked improvement and a saving in maintenance.

6. With the exception of the French Colonial Railways, an eight-hour day is compulsory, counting from the moment of arrival at the job.

The French Administrations, in conformity with legal requirements, calculate each kilometre which a man must travel both ways between his home and work, as equal to a reduction in work of 15 minutes, taking into account that the maximum distance he must travel on his own account must not exceed 5 km. (3.1 miles).

In the Colonial Administrations, the working day is longer, *viz.* 9 to 10 hours.

7. Of the two systems most generally employed for the maintenance of permanent way, *i. e.* general overhaul inspection or « walking » the first is used by most of the administrations, amongst whom the most important assert that they are completely satisfied with it.

Variable periods and itineraries are established according to the importance of the line and its traffic, but always between two and four years.

It is a pity that no economic comparison has been established between the two systems; the administrations who use them simply say they are satisfied.

Generally the ordinary maintenance gangs do the work.

8. The decision not to contract out is nearly general, nor to have piece work at bonus rates, although a very few administrations do this.

The prevailing opinion approves the work being done by the company, as otherwise one is liable to harmful consequences; and when contracted out, the work is never comparable to company's work, in which specially trained men are employed under strict supervision.

9. Transport of men to the job is at their expense. They nearly always walk. Some administrations have tried carrying them on mechanically propelled trolleys, and it must be recognised that this offers many advantages.

Not only do the men arrive rested and with the required energy for work, but the force required for urgent and necessary work can be got together at a given moment at the desired spot.

Travelling by bicycle belonging to the men is allowed, but only a very few administrations employ this means. There are some which make a small allowance to men who use them for getting to work.

10. Very few administrations have replied to the question regarding means employed for lengthening the life of road materials. And those who have replied only mention the impregnation of sleepers, tarring or galvanising the screws, insertion of plugs where screws have been withdrawn, etc.

11. The general reply is that graphs of work have not been compiled, from which results can be deduced not only of the length of time required but also the cost of the work, with all details requisite for satisfactory inspection and oversight in a good organisation.

12. For engaging permanent way men, different methods are employed according to their class, as follows :

For the ordinary men admission without examination is usual, and within most of the administrations, without requiring technical knowledge or experience.

Gang foremen in most cases are selected from among the men, and but rarely after previous examination.

Finally we have the district foreman, who is equivalent to a foreman of several gangs, an undoubtedly important post, for on him depends the proper maintenance of the permanent way and also success from the social point of view.

It is indisputable that these men should be endowed with the ability to direct, for they have under their orders large bodies of men, and must also deal with matters which are not german to road maintenance.

Practice differs, however, in this respect.

Free choice is practically never followed, seeing the importance of the job.

The system of selection is also rarely applied unless it be by requiring a preliminary examination or competition before a properly constituted jury, to whom the candidates demonstrate their theoretical and practical knowledge, and must also furnish a certificate of the services they have rendered.

For the preparation they must undergo before presenting themselves to the jury, several methods are recommended.

In the first place, the candidate should be quite free to choose his books and the instructor who is to teach him, according to the situation he holds, although this solution is always incomplete.

It would be well to enable prospective candidates to live where they can follow a suitable course of study.

And in this respect the administration

still plays an important part, favouring men who have degrees, if at the same time they have the knowledge necessary for the position to which they aspire.

Some administrations have a decided preference for this latter class, and even pay them a portion of their expenses incurred while studying, supplying them further with books, and even paying the school fees.

Lastly, there is another method which we consider very effective, and which is already employed by some administrations with excellent results. This is by organising classes at the cost of the administration and having as professors their own instructors, who plan the course and confer as to appropriate subjects.

Further, this method provides for prizes in the form of books, drawing materials, etc.

In view of the important part which these men take in the maintenance of permanent way and of the difficulty of finding public or private centres of instruction, we consider administrations should not hesitate to take upon themselves the instruction of their personnel.

This would place at their disposal a good number of men equipped with all that is necessary to fulfil their task. We are moreover certain that the tendency in the future will be definitely towards this system.

CONCLUSIONS.

1. In view of the short duration of the trials with mechanical tools for permanent way maintenance and the limited experience, member administrations are recommended to extend these trials, compiling with every possible care statistics and comparisons which might bring to fresh consideration of clear and well defined data.

2. The existence of gangs as primarily entrusted with permanent way maintenance may be considered as general, although the composition and strength are usually variable. Uniformity may be regarded as exceptional.

In order to decide the composition of the gangs and the length of track allotted them, it would be desirable to have available formulæ or coefficients, or comparisons of the widest general range, notwithstanding that their establishment may be difficult in face of the diversity of circumstances affecting them.

The average length of single track assigned to each man is 2 km. (1.24 miles).

It is desirable from every point of view to maintain uniform composition throughout the year by means of permanent gangs, which when necessary can be reinforced by casual labour.

3. To assure the greatest safety in permanent way maintenance, and effect at the same time an appreciable saving, the use of shovel tamping is recommended.

4. Generally the working day is eight hours, counting from arrival at the job.

5. General periodical inspection is adopted by most of the administrations who say they are satisfied with it; but it would be desirable to know the economical results, and if possible to establish a comparison with those obtained by « walking », so that the administrations may decide to employ (standardise) one of these two systems.

6. Owing to its importance, it is as well in general not to entrust the maintenance of permanent way to contractors, nor to have it done by piecework, or under bonus.

7. It would be interesting to get more definite information regarding experi-

ments in the transport of men to their job, as this offers indisputable advantages. Workmen might be encouraged to purchase bicycles themselves, and might receive a small allowance for their upkeep.

8. It would be as well to recommend adminitstrations to prepare well thought out graphs in which might appear not only the account of the work but also the necessary data for determining first cost of each of the individual operations included in permanent way maintenance.

9. As far as possible, the formation of technical schools by the administrations themselves, for the education for the post of district foreman, of candidates drawn from the lower grades — workmen and gang foremen — should become general.

Madrid, 10 March 1929.

TABLES 1, 2, 3, 4 and 5

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BELGIAN ADMINISTRATIONS.	F			
	Question 1.		Question 2.	Question 3.
	Annex.	Reply.		
1	2	3	4	5
Belgian National Railway Company.	a	No.	...	...
	b	No.	...	...
	c	Yes, since 1926.	Photo. fig. 1.	10 000 Belg. fr. fr. daily.
	d	No.	...	...
	e	No.	...	...
	f	Yes.	Trolleys with hoppers.	Each trolley 5 Belg. fr., 2.44 1 000 kgr.
	g	No.	...	...
	h	No.	...	...
	i	No.	...	...
	j	Yes.	Electric sets.	50 000 fr. and 2 fr. per set of e ment laid.
	k	Yes.	Special spanners, Robel type. Photo. fig. 2.	45 Gold-Mark
	l	No.	...	...
	m	No.	...	...
	n	No.	...	...
	o	Yes.	Mech. drilling for holes up to 32 mm.	3 000 Belgian fr
	p	No.	...	...
National Light Railway Company.	q	No.	...	...
	...	No.	...	...
Congo Railway Company . .	...	...	« Ochner » tipping wagons with saddle brakes and side doors.	...

T.

Question 4.	Question 5.	Question 6.	Question 7.
6	7	8	9
...	...	...	...
...	...	...	...
aving 50 % = 4 men.	5 km.	Reduction in staff = less storage.	Yes = not precise. Power driven.
...	...	...	...
...	...	...	...
aving per 1 000 km., 1 125 fr., 2 men.	5 km.	Reduction in cost, load and accidents.	Yes.
...	...	...	...
...	...	...	...
...	...	...	...
3 % = 3 men = 2 sets = 30 men.	10 km.	Saving in staff.	Yes.
50 % = 1 man.	Whatever the distance may be.	Speed of laying.	Yes.
...	...	...	...
...	...	...	...
...	...	...	...
Each hole costs 1 fr. By hand 5 fr. = 2 men.	On the stations.	By hand.	Yes.
...	...	...	...
...	...	...	...
...	...	...	...
...	...	...	...

TA

BELGIAN ADMINISTRATIONS.	SECO			
	Question 1.		Question 2.	Question 3.
	Annex.	Reply.		
1	10	11	12	13
Belgian National Railway Company.	A a	Gangs uniformly distributed.	Complete or partial methodical revision.	Flat bottom rail 50 kgr. with o lap joints, toget with 29 sleepers 18 m., without plate on strai road or curves more than 600 radius, with bal which must not river gravel.
	A b	On the important stations.		
	A c	For signals only.		
	B a	No.		
	B b	No.		
	B c	No.		
National Light Railway Company.	A a	Gangs uniformly distributed.	Careful observations with special cards for each kilometre.	Metre gauge with kgr. rails of 18 tres, with 15 pers. 1.435-m. g rail of 32.5 18 m. long. 20 pers. Overlap jo and ballast of riable quality.
	A b	No.		
	A c	No.		
	B a	...		
	B b	...		
	B c	...		
Congo Railway Company . . .	A	Gangs uniformly distributed.	No.	33-kgr. rais of 1 with 18 slee joints in fives, screw with sa bolt.

tinued).

stion 4.	Question 5.	Question 6.	Question 7.	Question 8.	Question 9.
14	15	16	16	18	19
km. double ; 7 to 10 ingle track; varies from 8 men.	There are formulæ and tables for obtaining the desired results according to the conditions of the line. Circular 11-8-26.	During the winter normal regime; augmented in summer.	Yes.	General inspection.	Normal gangs, augmented in the summer.
of foreman 4 to 5 men, looking af- 3 km.	No formulæ used.	Gangs reduced in winter and streugh thened in summer.	Yes.	Inspection troughout in favorable periods of the year. At other times general inspection.	Ordinary gangs.
nan looks af- 2 km.	No.	No.	Yes.	Walking the length.	Ordinary gangs.

BELGIAN ADMINISTRATIONS.	SE			
	Question 10.	Question 11.	Question 12.	Question
1	20	21	22	23
Belgian National Railway Company.	Sleepers are drilled and dressed beforehand. Ballasting by hand. The use of shovel tamping is growing. Weeding by hand.	No.	8 hours per day increased in special circumstances.	From arrival workman time he work.
National Light Railway Company.	Sleepers are impregnated by the Bethell method.	No. 39.47 + 45 Belgian fr.	8 hours.	From arri the work to time he work.
Congo Railway Company . . .	No.	No.	No.	No.

ntinued).

(continued).

Question 14.	Question 15.	Question 16.	Question 17.	Question 18.
24	25	26	27	28
ent trolleys, running as trains.	No, only a few electricians.	The dressed sleepers are fitted with bolts before being laid. Tarred trenails are to be used.	No.	Men engaged as needed. Gang foremen by examination after 2 years work. District foremen in competition amongst gang foremen.
No.	No.	On bridges with heavy traffic, and at cross-overs special steel is used.	No.	District and gang foremen are selected according to their capacity and ability to control without being submitted to competition or examination.
No.	No.	No.	No.	No.

T

SPANISH ADMINISTRATIONS.	F			
	Question 1.		Question 2.	Question 3.
	Annex.	Reply.		
1	2	3	4	5
Andalusian Railways	...	No.	...	...
Central Aragon Railway . .	...	No.	...	...
Madrid to Saragossa & to Alicante Railways.	...	...	No.	...
North of Spain Railways . . .	...	No.	...	...
Loroa to Baza Railway . . .	...	No.	...	...

Question 4.	Question 5.	Question 6.	Question 7.
6	7	8	9
...	...	..	...
...	...	...	...
...	...	...	...
...	...	...	...
..	..	..	...

T

SPANISH ADMINISTRATIONS.	SEC			
	Question 1.		Question 2.	Question 3.
	Annex.	Reply.		
1	10	11	12	13
Andalusian Railways	A a	Gangs uniformly distributed.	No.	Rails of 45 kgr., long with sl and sole pla varying numb
	A b	No.		
	A c	No.		
	B a	No.		
	B b	Yes.		
	B c	The same men.		
Central Aragon Railway . . .	A a	Gangs uniformly distributed.	No.	Rails of 42 1/2 a kgr. per metre, 12.4 m and sleepers.
Madrid to Saragossa and to Alicante Railways.	A a	Gangs uniformly distributed.	Shovel tamping has been tried, but without obtaining any definite information.	Rails of 45 kg m. long, wit sleepers and plates on sleeper.
	A b	Important stations.		
	A c	Interlockings and tunnels.		
	B a	On bridges and in tunnels.		
	B b	Yes.		
	B c	Special watchmen.		
North of Spain Railway . . .	A a	Uniform gangs but for variable lengths.	Periodical inspection bi-annually.	Rails of 42.8 k 12,4 m. with o joints on sl with sole plat
	A b	Concentrated at the stations.		
	A c	Interlockings and tunnels.	"	
	B a	Bridges and tunnels.		
	B b	Yes.		
	B c	Yes.		
Lorca to Baza Railway . . .	A a	Uniform gangs.	No.	30-kgr. rails of m. with 10 sle
	A b	No.		
	A c	No.		
	B a	No.		
	B b	No.		
	B c	No.		

inued).

...stion 4.	Question 5.	Question 6.	Question 7.	Question 8.	Question 9.
14	15	16	17	18	19
...er gang of ...	No.	Permanent and increased when there is special work.	The same gang.	Walking the length.	No.
...per gang of ...n.	No.	Do.	Do.	Do.	No.
...per gang of ...n.	No.	Do.	Do.	Do.	No.
... km. with 7	Yes, according to the number of points on a length of road.	Permanent and added to when there is special work.	Do.	Periodical inspection twice a year.	Normal staff.
...per gang of ...n.	No.	Do.	Do.	Walking the length	No.

SPANISH ADMINISTRATIONS.	SE			
	Question 10.	Question 11.	Question 12.	Question
1	20	21	22	23
Andalusian Railways	No.	Sometimes by piece work, but never under bonus.	8 hours.	Beginning fr rival at th
Central Aragon Railway. . .	No.	No.	8 hours.	Do.
Madrid to Saragossa and to Alicante Railways.	Preparing the sleepers and cleaning the ballast.	No.	8 hours. Overtime in urgent cases.	Do.
North of Spain Railway . . .	Do.	No.	Do.	Do.
Lorca to Baza Railway . . .	No.	No. 1 900 pesetas.	Do.	Do.

ontinued).

T (continued).

Question 14.	Question 15.	Question 16.	Question 17.	Question 18.
24	25	26	27	28
No.	No.	No.	No.	By selection.
No.	No.	No.	No.	No.
No.	No.	No.	No.	The formation of technical schools is being considered.
No.	No.	No.	An inspection chart is kept.	Free nomination of workmen and gang foremen. District foremen by examination.
No.	No.	No.	No.	By selection.

TABL

FRENCH ADMINISTRATIONS.	FIRS			
	Question 1.		Question 2.	Question 3.
	Annex.	Reply.		
	2	3	4	5
State Railways	...	Power-driven tampers, Collet type.	Photo, fig. 3.	50 000 fr. includin motor.
	...	Trolleys with trailers.	Photo, fig. 4.	50 000 and 7 500 f respectively.
	...	Cutters and drillers for sleepers, Collet type.	Photo, fig. 5.	...
	...	Tightening bolts.	...	...
	...	Chemical weeding.	Train of 1 tank wagon with pump for mixing, and 1 closed wagon for the solid ingredient.	85 000 fr. without th wagons.
	...	Tip wagons.	...	...
Alsace-Lorraine Railways. . .	...	...	No.	No.
Paris Girdle Railways . . .	...	...	No.	No.
Est Railway	b	Tip wagons.	...	...
	c	Special wagons for unloading rails.	Photo, fig. 6.	The additional featu costs 35 000 fr.
	f	Trolleys with trailers.	...	50 000 fr., 5 000 fr
	n	Chemical means and by hand.	With chl. of sodium & « occisol » tank wagon, wagon with pump and a supply of salt.	By mechanical mea 310 fr. per km. 80 000 fr. the instal tion. 180 or 200 fr. per k
	o	Cutting and drilling rails with worn ends for future use.	Travelling workshops. Photo, fig. 7.	36 000 fr.

Question 4.	Question 5.	Question 6.	Question 7.
6	7	8	9
…yet sufficiently tried … an authoritative …mparison of results.	Not yet sufficiently tried for an authoritative comparison of results.	Not yet sufficiently tried for an authoritative comparison of results.	When electrically driven can be used while road is in use.
…	…	…	…
…	…	…	…
…	…	…	…
…0.10 fr. per sq. me-…: a saving of 72 %.	20 km.	…	Yes.
…	…	…	…
No.	No.	No.	No.
No.	No.	No.	No.
…	…	…	…
… too short to give …sults.	3 km.	…	By hand.
…	…	…	Petrol motor.
…5 fr. per sq. metre.	…	…	…
…	…	…	Petrol motor.

TA[...]

FRENCH ADMINISTRATIONS.	Question 1.		Question 2.	Question 3.
	Annex.	Reply.		
1	2	3	4	5
Midi Railway	f	Trolleys and trailers.	...	24 000 fr.
	n	Chemical and mechanical means.	Tank wagon hauled by trolley. Photo, fig. 8.	50 000 fr.
Paris-Orleans Railway	f	Trolleys and hoppers.	...	...
Nord Railway	b	Auto-dumping wagons.	Photo, fig. 9.	...
	c	Special wagons.	Photo, fig. 6.	...
	f	Trolleys and hoppers.	...	...
	g	Drilling and adzing at the wharf.	...	...
	j	Electric machine for driving screws.	...	...
	n	Chemical weeding.	Photo, fig. 10.	...
Paris, Lyons & Mediterranean Railway.	b	Trolleys with tip-hoppers.	...	..
		Tamping ballast.	...	...
	d	Trolleys and hoppers.	Photo, fig. 11.	...
	f	Chemical and mechanical means.	..	...
	n			
Bouches-du-Rhône Railways and Tramways.	...	No.	No.	No.
Tarn Departmental Railways. .	...	No.	No.	No.

tinued).

(continued).

Question 4.	Question 5.	Question 6.	Question 7.
6	7	8	9
...	1.5 km.	...	...
not sufficient for ormation.	...	Labour saving.	Petrol motor.
...	...	..	Electric plant.
ving per ton 0.5 fr.	..	...	Electric plant.
ling of rails avoided.	...	...	...
...	...	...	...
...	...	...	Electric plant.
...	...	...	...
...	...	...	...
h only two years ex- erience cannot give xact information.	...	Saving and improvement in work, and reduction of hand labour.	Electric plant.
...	...	...	...
...	...	...	...
...	...	...	...
No.	No.	No.	No.
No.	No.	No.	No.

TA

FRENCH ADMINISTRATIONS.	FI			
	Question 1.		Question 2.	Question 3.
	Annex.	Reply.		
1	2	3	4	5
Somain to Anzin and the Belgian frontier	...	No.	No.	No.
Sud-Ouest Railway	...	No.	No.	No.
Société des Transports en commun de la région parisienne.	a	Pneumatic drills for breaking up the streets.	...	No.
	c	Automatic cranes on lorries.	...	No.
	d	Tamping with pneumatic hammers.	Photo, fig. 12.	No.
	e	Cutting and drilling rails.	Photos, figs. 13 & 14.	No.
Algerian State Railways . . .	...	No.	No.	No.
Paris, Lyons & Mediterranean (Algerian Lines).	...	No.	No.	No.
Tunisian Railway Company . .	f	Trolleys and hoppers.	Usual types.	...
	[illegible]	Machines for adzing and drilling.	« Compagnie Alsacienne » type.	...
French Colonial Railways in West Africa.	...	No.	No.	No.
Dahomey Railways	...	No.	No.	No.
Damas-Hamah and Extensions.	...	No.	No.	No.
Smyrna-Cassaba and Extensions.	...	No.	No.	No.
Indo-China.	...	No.	No.	No.

(continued).

RT *(continued).*

Question 4.	Question 5.	Question 6.	Question 7.
6	7	8	9
No.	No.	No.	No.
No.	No.	No.	No.
No.	No.	No.	No.
No.	No.	No.	No.
No.	No.	No.	No.
No.	No.	No.	No.
No.	No.	No.	No.
No.	No.	No.	No.
Very recent trials. Results not yet studied.	...	...	Ingersoll motors.
...	...	...	...
No.	No	No.	No.
No.	No.	No.	No.
No.	No.	No.	No.
No.	No.	No.	No.
No.	No.	No.	No.

TABLE

FRENCH ADMINISTRATIONS.	SECOND			
	Question 1.		Question 2.	Question 3.
	Annex.	Reply.		
1	10	11	12	13
State Railways	A a	Gangs uniformly distributed.	An organisation has been set up to check and supervise the proper carrying out of the rules for maintenance.	18-metre rails of 50 and 46 kgr. per metre with overlap on 27, 29 or 31 sleepers.
	b	Important stations.	...	...
	c	...	...	...
	B a	...	...	...
	b	Yes.	...	...
	c	Special watchmen.	...	...
Alsace Lorraine Railways . .	A a	Gangs of variable composition not uniformly distributed.	No.	18-m. rails of 46 kgr. per linear metre, with 27 or 30 sleepers per couple, with overlap joints.
	b	Important stations.	...	...
	c	For signals and electric installations.	...	...
	B a	Yes.	...	...
	b	Yes.	...	...
	c	Special watchmen.	...	...

inued).

tion 4.	Question 5.	Question 6.	Question 7.	Question 8.	Question 9.
14	15	16	17	18	19
of road to gang varies en 5 and 6 of double and 8 to m. single with suffi- men so that nay have 1 f double and km. of sin- ack to look	To be determined in accordance with previous coefficients.	Permanent, but added to on certain occasions.	Yes.	General periodical inspection every 2, 3 or 4 years according to the importance of the lines.	Ordinary gangs.
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
double and n. for sing- ck with 10 on impor- lines, and 6 men on dary lines.	There are comparative coefficients applicable to lengths of road of different installations.	Permanent gangs augmented during fine weather.	Yes.	General periodical inspection every 2, 3 or 4 years.	Ordinary gangs.
...	...	...	..	...	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...

T

FRENCH ADMINISTRATIONS.	SEC			
	Question 1.		Question 2.	Question 3.
	Annex.	Reply.		
	10	11	12	13
Paris Girdle Railways . . .	A a	Gangs of variable composition and distribution.	Shovel packing has been adopted.	18-m. rails of 4[illegible] on 27 sleepers overlap joints
	A b	Large stations.	...	...
	A c	Given out to contractors.	...	...
	B a	Yes.	...	...
	B b	Yes.	...	...
	B c	Special men.	...	...
Est Railway.	A a	Gangs of variable composition and distribution.	Shovel packing has been adopted.	18-m. rails of 4[illegible] on 27 sleepers overlap joints
	A b	No.	...	...
	A c	Metal spans.	...	...
	B a	No.	...	...
	B b	Yes.	...	...
	B c	Special men.	...	...
Midi Railway	A a	Gangs of variable composition and distribution.	Shovel packing has been adopted.	22-m. bull-headed 44 kgr. per [illegible] metre, with sleepers.
	A b	Large stations.	...	...
	A c	No.	...	...
	B a	No.	...	...
	B b	Yes.	...	...
	B c	No.	...	...

ontinued).

T *(continued).*

uestion 4.	Question 5.	Question 6.	Question 7.	Question 8.	Question 9.
14	15	16	17	18	19
m. of double ck with 7 men	No.	Permanent size, added to if necessary.	Yes.	General inspection.	Ordinary gangs.
..	...	...	..	...	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	..	...	...
...	...	...	...	...	...
6 km. with to 5 men.	No.	Permanent size, added to if necessary.	Yes.	General inspection.	Ordinary gangs.
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
8 km. double nd 7 to 8 km. ingle track, or to 4 km. on ouble track, and to 5 on single ccording to the nes.	No.	Permanent composition added to if necessary.	Yes.	General periodical inspection every 3 or 4 years.	Ordinary gangs.
...	...	...	...	..	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...

TAB[...]

FRENCH ADMINISTRATIONS.	SECON[...]			
	Question 1.		Question 2.	Question 3.
	Annex.	Reply.		
1	10	11	12	13
Paris-Orleans Railway. . . .	A a	Gangs uniformly distributed but not of fixed composition.	No.	16.51-m. rails, 45 k[...] and 55 kgr. for tu[...] nels with 27 sle[...] pers and overl[...] joints.
	b	Yes.	...	...
	c	No.	...	...
	B a	No.	...	...
	b	Yes.	...	..
	c	Special watchmen.	...	..
Nord Railway	A a	Gangs uniformly distributed.	Shovel packing.	Standard 18 m.-ra[...] of 46 kgr.
	b	Being tried.	...	...
	c	In case of need, not as a rule.	...	...
	B a	No.	...	...
	b	Yes.	...	...
	c	No special watchmen.	...	...
Paris, Lyons & Mediterranean Railway.	A a	Gangs uniformly distributed.	Reduction of the length allotted to each gang.	18-m. rails of 46 k[...] with overlap join[...]
	b	No.	...	...
	c	No.	...	...
	B a	No.	...	...
	b	Yes.	...	...
	c	Special men.	...	...

ntinued).

(continued).

uestion 4.	Question 5.	Question 6.	Question 7.	Question 8.	Question 9.
14	15	16	17	18	19
7 km. double; to 10 single ck.	No.	Permanent composition. Added to if necessary.	Yes.	General periodical revision every 2, 3 or 4 years.	Ordinary gangs.
...	...	...	...	...	...
...	...	...	...	...	...
..	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
ack roads = km. single ck with 9 men. oads = 11 km. ad.	Number of points per length of road: 1 single slip per 100 m. of road. 1 double slip per 300 m. of road.	Fixed gang during the winter. Added to in summer.	Yes.	General periodical inspection.	Ordinary gangs.
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	..
...	...	...	...	...	...
m. of double ack with 6 en.	We use simple coefficients.	Permanent composition. Added to if necessary.	Yes.	General periodical inspection every 3 to 6 years.	Ordinary gangs.
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...

TABL[...]

FRENCH ADMINISTRATIONS.	SECON[...]			
	Question 1.		Question 2.	Question 3.
	Annex.	Reply.		
1	10	11	12	13
Bouches-du-Rhône Railways and Tramways.	A a	Uniform gangs distributed as convenient.	No.	Rails of 34.4 kgr. wit[...] 6 to 8 sleepers p[...] couple.
	A b	No.	...	...
	A c	No.	.	...
	B a	No.	...	...
	B b	Yes.	...	...
	B c	Special men.	...	...
Tarn Departmental Tramways.	A a	Gangs uniformly distributed.	No.	Rails of 20 kgr. wit[...] 16 sleepers per co[...]ple.
	A b	No.	...	...
	A c	No.	...	...
	B a	No.	...	...
	B b	No.	...	...
	B c	No.	...	...
Somain to Anzin and the Belgian Frontier Railway.	A a	Gangs uniformly distributed.	No.	12-m. rails of 32.4 kg[...] with overlap join[...] and 16 sleepers.
	A b	No.	...	...
	A c	No.	...	...
	B a	No.	...	...
	B b	Yes.	...	...
	B c	Special watchmen.	...	.
Sud-Ouest Railways.	...	...	...	...

inued).

ontinued).					
tion 4.	Question 5.	Question 6.	Question 7.	Question 8.	Question 9.
14	15	16	17	18	19
ith 4 men	No.	Permanent composition. Added to if necessary.	Yes.	Walking the length	No.
...	...	...	...	...	..
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
ith 5 men.	No.	Permanent gang added to it necessary.	Yes.	Walking the length	No.
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	..	...	...
...	...	...	...	...	...
ith 5 men.	$N = 1.3\ L + 2.5\ p. + 0.5\ h.$, when N = number of men, L = length of single track, P = number of junctions, stations, etc., h = length of tracks in stations.	Permanent. Added to if necessary.	Yes.	Walking the length	Ordinary gang.
...	...	..	...	...	..
...	...	..	...	...	...
...	...	...	...	..	...
...	...	..	...	...	..
...	...	...	...	..	.
ith 4 men.	No.	Permanent. Added to if necessary.	Yes.	Walking the length	No.

TA

FRENCH ADMINISTRATIONS.	SECO			
	Question 1.		Question 2.	Question 3.
	Annex.	Reply.		
1	10	11	12	13
Société des Transports en commun de la région parisienne.	...	...	...	...
Algerian State Railways . . .	A a	Fixed gangs. Variable distribution.	No.	12-m. rails of 46 k with 17 sleepers
	A b	No.	...	...
	A c	Metal spans.	...	...
	B a	Yes.	...	...
	B b	Yes.	...	...
	B c	Yes.	...	...
Paris, Lyons & Mediterranean Railway (Algerian Lines).	A a	Composition of gangs fixed. Distribution variable.	No.	18-m. rails, 46 k 18 to 24 sleeper
	A b	No.	...	...
	A c	Special watchmen.	...	...
	B a	No.	...	...
	B b	Yes.	...	...
	B c	Special watchmen.	...	...
Tunisian Railway Company . .	A a	Fixed gangs. Variable distribution.	Experimental increases of length per gang, transporting the men by wagon, would seem to give good results.	12-m. rails of 46 k with 16 sleepers overlap joints.
	A b	No.	...	...
	A c	No.	...	...
	B a	No.	...	...
	B b	Yes.	...	...
	B c	Special watchmen.	...	...

ntinued).

(continued).

estion 4.	Question 5.	Question 6.	Question 7.	Question 8.	Question 9.
14	15	16	17	18	19
...	...	...	...	General inspection.	...
with 6 men.	No.	Permanent. Added to when required	Yes.	General inspection.	Ordinary gangs.
...	...	..	...	...	...
..	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
with 5 men.	No.	Permanent. Added to when needed.	Yes.	General inspection and walking according to the lines.	Ordinary gangs.
...	...	..	...	...	...
...	...	...	...	...	...
...	...	...	..	...	...
...	...	...	...	...	...
...	...	...	...	...	...
with 4 men.	No.	Permanent. Added to when needed.	Yes.	General inspection every 3 to 4 years.	Ordinary gangs.
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...

TA[...]

FRENCH ADMINISTRATIONS.	SECO[...]				
	Question 1.			Question 2.	Question 3.
	Annex.		Reply.		
1	10		11	12	13
French Colonial Railways in West Africa.		a	Fixed gangs. Uniform distribution.	No.	Rails of 30 kgr. [...] metre with me[...] sleepers.
Dahomey Railways	A	a	Fixed gangs. Variable distribution.	No.	8-m. rails of 22 k[...] with metal sleep[...]
		b	Special watchmen.	...	...
		c	No.	...	...
	B	a	No.	...	...
		b	No.	...	...
		c	No.	...	...
Damascus-Hamah and Extensions.	A	a	Uniform gangs. Variable distribution.	No.	9.155-m. rails of [...] kgr. with 11 me[...] sleepers.
		b	No.	...	...
		c	No.	...	...
	B	a	No.	...	...
		b	Yes.	...	...
		c	No.	...	..
Smyrna to Cassaba and Extensions.	A	a	Uniform gangs. Variable distribution.	No.	11.60-m. rails o[...] kgr. 14 metal s[...]pers.
		b	No.	...	..
		c	Metal spans.	...	...
	B	a	Metal spans.	...	...
		b	Yes.	...	...
		c	Special watchmen.		...
Indo-China	A	a	Uniform gangs. Variable distribution.	No.	17-m. rails of 26 [...] with 17 sleepe[...]
		b	No.	...	...
		c	No.	...	...
	B	a	Metal spans.	...	...
		b	Yes.	...	...
		c	Special watchmen.	...	...

continued).

RT (*continued*).

Question 4.	Question 5.	Question 6.	Question 7.	Question 8.	Question 9.
14	15	16	17	18	19
m. with 8 men.	No.	No.	Yes.	Walking the length.	...
m. with 4 men.	No.	Permanent. Added to when needed.	Yes.	Walking the length.	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
1/2 to 10 km. 6 to 7 men.	No.	Permanent. Added to when needed.	Yes.	General inspection and walking the length.	Ordinary gangs.
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
km. with 6 men.	No.	Permanent. Added to when needed.	Yes.	Walking the length.	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
..	...	...	...	...	...
m. with 8 men.	No.	Permanent. Added to when needed.	No.	General inspection.	Ordinary gangs.
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...

TABL

FRENCH ADMINISTRATIONS.	SECON			
	Question 10.	Question 11.	Question 12.	Question 13.
1	20		22	23
State Railways	Preparing sleepers at special wharves.	No.	Yes.	Work is reckone by the statutor hours, but whe men have to tra vel more tha 5 km. they re ceive an allow ance equal t 15 minutes wor per km.
Alsace-Lorraine Railways . .	Preparing sleepers, tarring the « material » in tunnels. Destroying weeds by « Occisol ».	No.	8 hours.	Work is reckone by the statutor hours, but whe men have to tra vel more tha 5 km. they re ceive an allow ance equal t 15 minutes wor per km.
Paris Girdle Railways	Sleepers prepared in the yard. Ballast cleaned by hand, mechanical means having been employed only for a short time.	No.	8 hours.	Work is reckone by the statuto hours, but whe men have to tr vel more tha 5 km. they r ceive an allo ance equal 15 minutes wo per km.
Est Railway	No.	Bonuses at the general inspection.	8 hours.	Work is reckon by the statuto hours, but wh men have to t vel more th 5 km., they ceive an allo ance equal 15 minutes wo per km.

continued).

RT (*continued*).				
Question 14.	Question 15.	Question 16.	Question 17.	Question 18.
24	25	26	27	28
No.	No.	No.	No.	Free choice for lower grades, whom the section foremen train by lectures and distribution of books and diagrams.
No.	No.	No.	A chart is kept for each gang.	Free choice of men. Examination for gang and district foremen.
No.	No.	No.	No.	Foremen are appointed by competition, but must first undergo a course of instruction.
No.	No.	No.	No.	Foremen are appointed by competition, but must first undergo a course of instruction.

TABLE

FRENCH ADMINISTRATIONS.	SECOND			
	Question 10.	Question 11.	Question 12.	Question 13.
1	2	21	22	23
Midi Railway	Sleepers are prepared, and bolts and screws tarred.	No.	8 hours.	Work is reckoned by the statutory hours, but when men have to travel more than 5 km., they receive an allowance equal to 15 minutes work per km.
Paris-Orleans Railway. . . .	Sleepers are prepared, and bolts and screws tarred.	No.	8 hours.	Work is reckoned by the statutory hours, but when men have to travel more than 5 km., they receive an allowance equal to 15 minutes work per km.
Nord Railway.	Sleepers are prepared, and bolts and screws tarred.	No.	8 hours.	Work is reckoned by the statutory hours, but when men have to travel more than 5 km., they receive an allowance equal to 15 minutes work per km.
Paris, Lyons & Mediterranean Railway.	Preparation of sleepers.	No.	8 hours.	Work is reckoned by the statutory hours, but when men have to travel more than 5 km. they receive an allowance equal to 15 minutes work per km.

ntinued).

(*continued*).				
uestion 14.	Question 15.	Question 16.	Question 17.	Question 18.
24	25	26	27	28
No.	No.	No.	No.	Free selection and elmentary examination.
No.	No.	No.	No.	Free selection and elmentary examination.
No.	Men who have bicycles get a fixed allowance.	No.	Charts of the progress of the work.	Free selection and elmentary examination.
No.	No.	Increase in depth of ballast.	Gang foreman's annual chart.	Examination for district foremen who are authorised to attend a course of instruction at technical schools, half the fees being paid for them.

TABL

FRENCH ADMINISTRATIONS	SECON			
	Question 10.	Question 11.	Question 12.	Question 13.
1	20	21	22	23
Bouches-du-Rhône Railways and Tramways.	No.	No.	8 hours.	Work is reckon according to sta tutory hours, bu when men hav to travel mor than 5 km. the receive an allo ance equal to 1 minutes work p km.
Tarn Departmental Railways .	No.	No.	8 hours.	Work is reckon according to st tutory hours, b when men hav to travel mo than 5 km. th receive and a lowance aqual 15 minutes wo per km.
Somain to Anzin and the Belgian Frontier Railways.	Preparing sleepers.	No bonuses.	8 hours.	Work is reckon according to st tutory hours, b when men ha to travel mo than 5 km. th receive an allo ance equal 15 minutes wo per km.
Sud-Ouest Railways.	No.	No.	8 hours.	Work is reckon according to st tutory hours, b when men ha to travel mo than 5 km. th receive an allo ance equal 15 minutes wo per km.
Société des Transports en commun de la région parisienne.	No.	No.	No.	No.

ontinued).

T (*continued*).				
Question 14.	Question 15.	Question 16.	Question 17.	Question 18.
24	25	26	27	28
No.	Workers get 10 fr. per month for upkeep of bicycle.	No.	No.	Competition between men.
No.	No.	No.	No.	Competition between men.
No.	No.	No.	No.	Free choice and selection.
No.	No.	No.	No.	No.
No.	No.	No.	No.	No.

TABL[E]

FRENCH ADMINISTRATIONS	SECON[D]			
	Question 10.	Question 11.	Question 12.	Question 13.
1	20	21	22	23
Algerian State Railways . . .	No.	No.	8 hours.	Work is reckone[d] according to sta[-]tutory hours, bu[t] when men hav[e] to travel mor[e] than 5 km. the[y] receive an allow[-]ance equal t[o] 15 minutes wor[k] per km.
Paris, Lyons & Mediterranean Railway (Algerian Lines).	No.	No.	8 hours.	Work is reckone[d] according to sta[-]tutory hours, bu[t] when men hav[e] to travel mor[e] than 5 km. the[y] receive an allow[-]ance equal t[o] 15 minutes wor[k] per km.
Tunisian Railway Company . .	Preparation of sleepers, and tarring of screws.	No.	8 hours.	Work is reckone[d] according to sta[-]tutory hours, bu[t] when men hav[e] to travel mor[e] than 5 km. the[y] receive an allow[-]ance equal t[o] 15 minutes wor[k] per km..
French Colonial Railways in West-Africa.	No.	No.	...	...
Dahomey Railways	Preparation of sleepers.	No.	10 hours.	No.
Damascus to Hamah and Extensions.	No.	No.	10 hours.	No.
Smyrna-Cassaba and Extension.	No.	No.	9 1/2 hours.	...
Indo-China	No.	No.	9 hours.	...

tinued).

(continued).				
uestion 14.	Question 15.	Question 16.	Question 17.	Question 18.
24	25	26	27	28
No.	No.	No.	Chart of the progress of the inspection.	Free choice, selection and examination. The certificate of some schools is taken into consideration.
No.	No.	No.	No.	Free choice, selection and examination. The certificate of some schools is taken into consideration.
been tried.	No.	No.	No.	The administrations at Tunis have a school for the education of district and gang foremen.
No.	No.	No.	No.	No.
No.	No.	No.	No.	No.
No.	No.	No.	No.	No.
No.	No.	No.	No.	Free choice, selection and examination.
No.	No.	No.	No.	Free choice, selection and examination.

TAB

ITALIAN ADMINISTRATIONS.	FIR			
	Question 1.		Question 2.	Question 3.
	Annex.	Reply.		
1	2	3	4	5
State Railways	d	Motor-driven tampers on lorries.	See photo, fig. 3.	90 000 lires the mo set.
	f	Trains of lorriés and hoppers.	..	Each lorry ab 15 000 lires. hopper about 6 lires.
	g	Dressing and drilling the sleepers in the shops.	...	...
	j	Motor-driven tools mounted on lorries.	...	...
	n	A special machine patented in Switzerland is used mounted on a wagon, and hauled by an engine.	...	...

Question 4.	Question 5.	Question 6.	Question 7.
6	7	8	9
40 % saving.	...	...	Petrol motor set, moved every km.
...	...	Chiefly to effect inspection rapidly in malarial districts.	...
...	...	...	..
40 % saving.	...	...	...
...	...	...	...

T

ITALIAN ADMINISTRATIONS.	SEC			
	Question 1.		Question 2.	Question 3.
	Annex.	Reply.		
1	10	11	12	13
State Railways	A a	Gangs non-uniformly distributed.	The whole upkeep of the road has been placed out to contract and an appreciable saving has been effected.	18-m. rails of 46.3 per linear (m but for tunne special type of kgr.rails. Ov joints, 25, 26 sleepers per All sleepers hav le plates.
	A b	In the main stations.	...	...
	A c	No.	...	...
	B a	No.	...	...
	B b	Yes.	...	...
	B c	Special watchmen.	...	...

ITALIAN ADMINISTRATIONS.	SEC			
	Question 10.	Question 11.	Question 12.	Question 1
1	20	21	22	23
State Railways	Sleepers are prepared in the shops. Shovel packing is used. Sifting (or sorting) the ballast.	Piece work is declined. Bonus work is being tried. 34 000 lires.	8 hours.	Begins on a at the job.

ontinued).

T.

Question 4.	Question 5.	Question 6.	Question 7.	Question 8.	Question 9.
14	15	16	17	18	19
7 km. on both uble and single ack with 10 to men as the se may be.	Co-efficients are used to determine the size of the gangs, reducing to a certain length of road the different installations.	Permanent. In certain cases the maintenance is given out to contract.	Yes.	General periodical inspection, according to the line every 4, 3 or 2 years.	Usual gangs and contractors.
...	...	...	...	...	...
...	...	...	..	...	...
...	...	...	...	...	...
..	...	...	..	...	...
...	...	...	...	...	...

T *(continued).*

Question 14.	Question 15.	Question 16.	Question 17.	Question 18.
24	25	26	27	28
No.	No.	Impregnating sleepers and galvanising screws.	No.	Free selection for lower grades. District and gang foremen by examination. The Administration will supply suitable books.

TABL

PORTUGUESE ADMINISTRATIONS.	FIRS			
	Question 1.		Question 2.	Question 3.
	Annex.	Reply.		
1	2	3	4	5
Portuguese Railway Company .	g	Dressing and drilling machines for sleepers in the shops.	...	...

PORTUGUESE ADMINISTRATIONS.	SECON				
	Question 1.			Question 2.	Question 3.
	Annex.		Reply.		
1	10		11	12	13
Portuguese Railway Company .	A	a	Gangs of variable size according to the traffic.	Stone crushing machines, and quadricycles for the men, have been bought recently.	18-m. rails of 45 kg per linear metr with 26 sleepers.
		b	No.	...	..
		c	On or at bridge.	...	...
	B	a	Bridges and tunnels.	...	...
		b	Yes.	...	...
		c	The same gangs.	...	...

PORTUGUESE ADMINISTRATIONS.	SECON			
	Question 10.	Question 11.	Question 12.	Question 13.
1	20	21	22	23
Portuguese Railway Company .	Preparation of sleepers in the shops.	A premium of 3 300 escudos is allotted to foremen of gangs which work the quickest and best.	8 hours.	Reckoned from a rival on the jo

RT.

Question 4.	Question 5.	Question 6.	Question 7.
6	7	8	9
50 %.	...	Saving in labour.	Yes.

RT.

Question 4.	Question 5.	Question 6.	Question 7.	Question 8.	Question 9.
14	15	16	17	18	19
km. for double rack and 10-km. ingle track with and 7 men.	No.	Permanent gangs, reinforced by casual labour.	Yes.	General inspection twice a year.	No.
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...

RT (*continued*).

Question 14.	Question 15.	Question 16.	Question 17.	Question 18.
24	25	26	27	28
No.	No.	No.	No.	Free election of lower grades, after selection. Persons in authority must attend the official technical schools for their particular course of instruction.

[621. 134]

REPORT No. 5

(Germany)

ON THE QUESTION OF IMPROVEMENTS IN THE STEAM LOCOMOTIVE (SUBJECT VI FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION) (1) (2),

By R. P. WAGNER,

Reichsbahnoberrat, Deutsche Reichsbahn Gesellschaft (German State Railway Company).

Figs. 1 to 46, pp. 101 to 144.

SUMMARY.

Possibilities of improvement by elaborating the theoretical principles, by further developing existing details and by perfecting constructional methods.

Increasing the pressure in normal locomotive boilers. Raising the degree of superheat. The progress of superheater design and the basis of the present form. — Suggestions for the more accurate determination of boiler dimensions. — Adaptation to superheating of other parts such as regulators, valves, pistons, cylinders, pressure equalisers, etc. Economising in steam consumption. Principles to be observed in regard to valve motion. Simple and multiple expansion, two and three cylinder simple locomotives.

Progress in methods of lubrication to meet the increase in steam temperature.

Preheating of feed water by combustion gases and by exhaust steam. — Development of accessories required with feed water heating. Recovery of condensate, sludge separators. Success attained.

Improvement in the Stephenson type of locomotive must be considered under two heads. Firstly, there are the results which can be attained by elaborating the theoretical determination of the data necessary for designing a new locomotive, with a view to replacing purely empirical determination by definite command over all the functions involved. Then there are improvements on the practical side and in the direction of greater efficiency of energy transformation.

In spite of its long period of development, the locomotive even today remains at a stage where the complex relations of the individual factor necessitate basing the design on accumulated experimental data. The difficulty of working with numerous variables compels the designer to rely largely on the results of tests. Only when the research engineer has

(1) This question runs as follows : « Improvements in the steam locomotive. Increased pressures and higher superheats. Improvements in the design of superheaters and parts connected with superheating. Feed water heating and air preheating. Improvement of valve gears. »

(2) Translated from the German.

cleared up the many problems that lie before him will it be possible to design a new locomotive, with the assurance that its maximum performance can be foretold accurately. The following discussion of the various items will indicate how far the Deutsche Reichsbahn has been successful in solving some of these problems on the basis of exact research, on better methods of obtaining designing data, even though this dealt in the first place with isolated factors.

On the constructional side, the Deutsche Reichsbahn had a special opportunity of making progress during the last few years by reason of the necessity for dealing with the operating and economic handicap imposed on them by a collection of locomotives of the most varied types from a large number of hitherto independent lines. Standard locomotives of the most modern design were required with as few types as would be consistent with economical working of the extensive network of lines.

Standardisation of the rolling stock as a whole, and of component parts manufactured on an interchangeable basis with tolerances to suit operating and workshop conditions, has led to the production of locomotives embodying the very latest ideas in modern construction.

On the Reichsbahn we consider the question of improved energy transformation along two entirely separate lines, both of which have been followed up with equal vigour. Firstly, there is the development of entirely new types by adaptations from stationary machines, such as increasing the pressure to the highest possible figure, the use of the turbine and with it of condensing; pulverised fuel or the Diesel engine. Secondly, there is the systematic development of the old types, as in the case of the standard locomotives already mentioned. Opportunties for effective and appreciable progress in this direction have been limited during the last 30 years. Compounding, superheating and feed water heating have certainly justified themselves by considerable savings in consumable stores, but further success is still possible by giving attention to many apparently small details.

More than 10 years ago the prevailing pressure on the Deutsche Reichsbahn was 12 atmospheres (170.7 lb. per square inch), and although this was exceeded here and there in particular classes of locomotives on the former State railways, the systematic use of higher pressures was not considered favourably. Experience with two and three-cylinder locomotives of types 1 D and 1 E and belonging to classes G 8^2, G 8^3 and G 12 showed that occasional boiler troubles necessitated the pressure being reduced from 14 to 12 atmospheres (199.1 to 170.7 lb. per sq. inch), and that this resulted in an increased consumption of from 5 to 7 % per effective horse-power hour, based on heat units in the coal used. This led to the adoption of 14 atmospheres (199.1 lb. per sq. inch) and in some cases 16 atmospheres (227.6 lb. per sq. inch) for the new standard locomotives. It was possible to avoid boiler troubles by suitable design features resulting in a form of firebox end which has not given rise to the slightest misgivings since the first machines of this type were put into service. These features included almost vertical walls with the water space widening out continuously in an upward direction to secure easier escape of the steam hubbles, thorough rounding off at all changes of section, and careful attention to adequate provision for expansion in all surfaces exposed to considerable temperature stresses. It is inherently difficult to

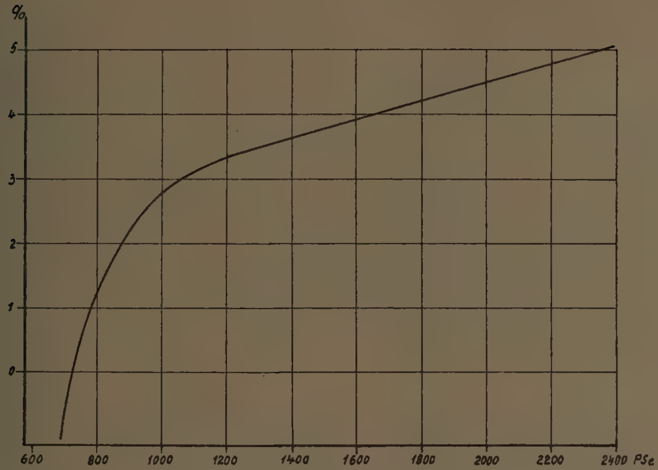


Fig. 1. — Saving in heat consumption with a boiler pressure of 16 at. (227.6 lb. per sq. inch) as compared with 14 at. (199.1 lb. per sq. inch).

Explanation of German terms : PSe = Effective H. P.

assess accurately the saving obtained by using a higher pressure, since in most cases this involves comparing machines belonging to widely different stages of development and in which economies had been introduced by other improvements also. Hence only a few of the newer standard locomotives were available, *e. g.*, series 01 of two-cylinder type 2 C 1, with which parallel test could be made at boiler pressures of 16 and 14 atmospheres (227.6 and 199.1 lb. per sq. inch). The results are shewn in figure 1 from which it will be seen that some 4 to 5 % may be attributed to the higher pressure. The sharp drop in the savings curve with decreasing load is due to throttling and the increased heat units per unit of output. The absolute magnitude of the saving effected will be discussed later; it depends very much on the particular locomotive. The type used in the above-mentioned tests was the latest design of the Reichsbahn which had a low consumption to start with, for which the increased pressure was only partially responsible.

The increase of boiler pressure has not yet reached its limit, although above 16 atmospheres (227.6 lb. per sq. inch) difficulties occur with ordinary boiler materials owing to questions of weight, unless, of course, an engine with a greater heat efficiency is employed, in which case the boiler can be smaller to start with. The low-pressure turbine is a case in point. For the same output as the 01 locomotive already cited, the heating surface is 33 % less, and the corresponding reduction in weight could be made use of to increase the pressure. The table (fig. 2) shows that the boiler weight of the standard locomotive is just about reached again at 22 atmospheres (312.9 lb. per sq. inch). On the other hand the specific weight is

Used on locomotives :	Pressure.	Grate area.	Evaporative heating surface.	Heating surface exposed to fire.	Superheater surface.	Number an	
						Smoke tubes.	Superheater elements.
	atm. (lb. per sq. inch).	m² (sq. feet)	m² (sq. feet)	m² (sq. feet)	m² (sq. feet)	mm. (inches)	mm. (inches)
01	16 (227.6)	4.5 (48.4)	238 (2562)	17 (183)	100 (1076)	135/143 (5 5/16-5 5/8)	30/38 (1 3/16-1 1
01 and second design.	16 (227.6)	4.5 (48.4)	247 (2928)	17 (183)	86 (926)	163/171 (6 7/16-6 3/4)	23/29 (15/16-1 3/
Maffei turbine	22 (312.9)	3.5 (37.7)	160 (1722)	13 (140)	51 (549)	129/137 (5 5/64-5 3/8)	29/36 (1 3/16-1 7/

Fig.

increased by from 24 to 36 % as compared with a boiler for 16 atmospheres (227.6 lb. per sq. inch). The figures in lines 1 and 2 relate to boilers for the same locomotive, the difference being that the second line indicates the further saving in weight that can be effected by appropriate dimensioning, as will be shewn later. Nevertheless, the figures show that it has already become necessary to adopt special measures to enable the Stephenson boiler to be retained on a normal locomotive for a higher steam pressure. As an example of this, experiment is being made with new boiler materials for a 25-atmosphere (355 lb. per sq. inch) boiler; the design is not yet available for publication.

The Maffei Locomotive Works have proved that a boiler for 22 atmospheres (312.9 lb. per sq. inch) can be successfully realised in Germany by the excellently designed turbine locomotive T 18 1002. The boiler is reproduced in figure 3; it does not deviate from the recognised form of boiler except in the thickness of the walls and the size of the tie bars. The saving due to this increase in pressure cannot yet be stated since exact measurements are not available, although numerous runs have been made. The behaviour in service is also of interest, and on this point it may be said that the boiler in particular has given rise to no difficulties of any kind. This result is due in no small measure to the application of the constructional principles previously discussed in relation to the boilers of the standard locomotives. Thus the firebox has a cylindrical top, vertical side walls, strong but flexible staying and first-class workmanship. The flat surfaces of the back plate above the firebox top are tied to the main boiler barrel by cast-steel brackets and four tie bars.

The boiler weight, however, is 194 kgr. per square metre (39.73 lb. per sq. foot)

of tubes.		Boiler diameter.	Volume of water space.	Steam space.	Evaporative surface.	Nett weight	Weight per unit surface.	Weight compared to	
Superheater flue tubes.	Number of tubes.							1	2
mm. nches)	—	mm. (feet & inches)	m^3 (cubic feet)	m^3 (cubic feet)	m^2 (sq. feet)	Metric (English) tons.	kgr. per m^2 (lb. per sq. foot)	o/o	o/o
49/54 /16-2 1/8)	43/129	1900 (6 ft. 2 3/4 in.)	9.15 (323)	4.5 (159)	13 5 (1.45)	37.7 (37.1)	157 (32.15)	...	+ 10.6
55/70 16-2 3/4)	24/106	1900 (6 ft. 2 3/4 in.)	10.48 (370)	5.1 (180)	15.1 (162.5)	35.70 (35.1)	145 (29.70)	− 7 7	...
1.5/56 2 13/64)	30/100	1600 (5 ft. 3 in.)	7.27 (257)	2.98 (159)	9.9 (106.5)	31 (30.5)	194 (39.73)	+ 23.6	+ 34

of heating surface which is as much as 36 % more than that of the boiler for 16 atmospheres (227.6 lb. per sq. inch).

From the outset more importance has been attached to the question of increasing the superheat than to higher steam pressure. This was due to the obvious reason that the economies to be obtained by superheating are considerably more important and can be achieved by comparatively simple means. In order to appreciate the manner in which this subject is now being dealt with, it is essential to review its development and the investigations that have been made.

The requirements of the Reichsbahn in respect of superheaters are as follows :

1) The economical production of an adequate degree of superheat up to 400° C. (752° F.) *i. e.*, with the least possible additional weight and with economical flue-gas temperatures.

2) Moderate first cost combined with reasonable maintenance expenditure and maximum life.

3) The superheater must be accessible itself and must not interfere with the accessibility or efficiency of other portions of the locomotive. The limited space on a locomotive renders this difficult.

Several types of superheaters were investigated from the point of view of these requirements and the results indicated the direction in which improvements could be sought.

The close linking in parallel of two substantially similar heating surfaces for evaporation and for superheating such as occurs in most of the smoke tube superheaters now in use, renders a purely mathematical treatment of what occurs in a locomotive superheater extremely difficult. This explains why the steam and flue-gas velocities have hitherto generally

Copper staybolts W 28 = 1/40° 0.5 p. Diameter of body 24.5 mm. (31/32 inch). Hole 4 mm. (5/32 inch).

30 superheater tubes
100 water tubes 5

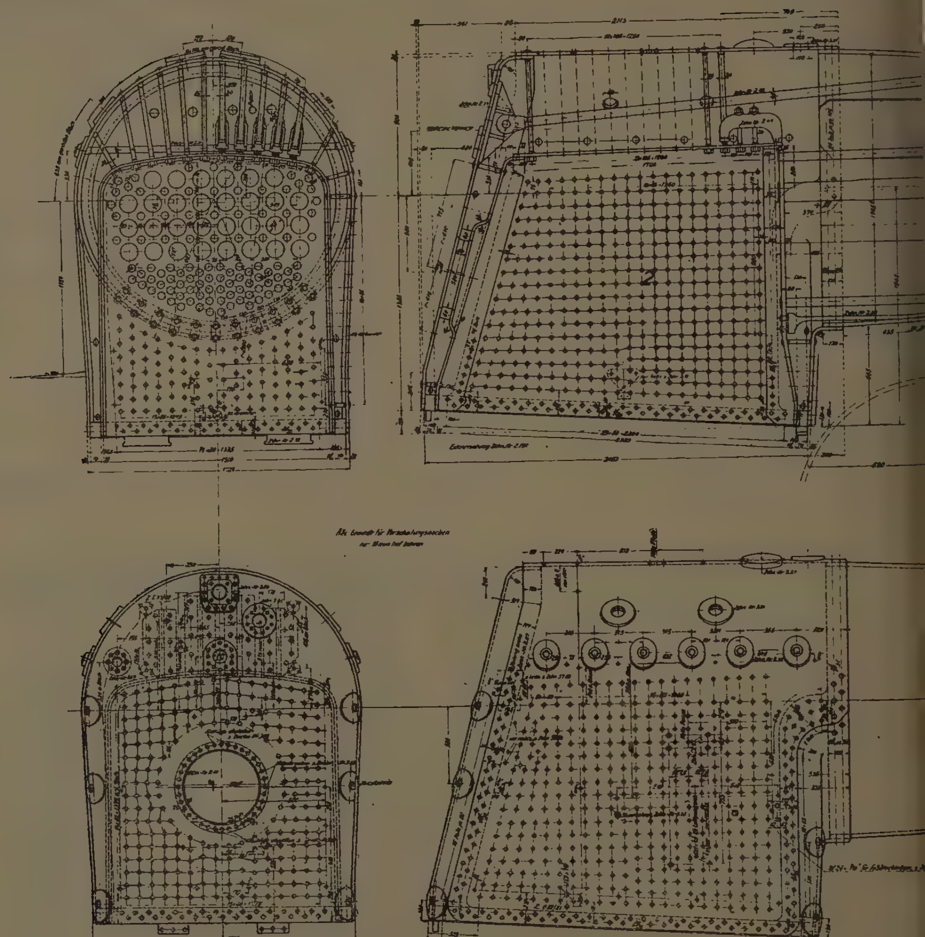


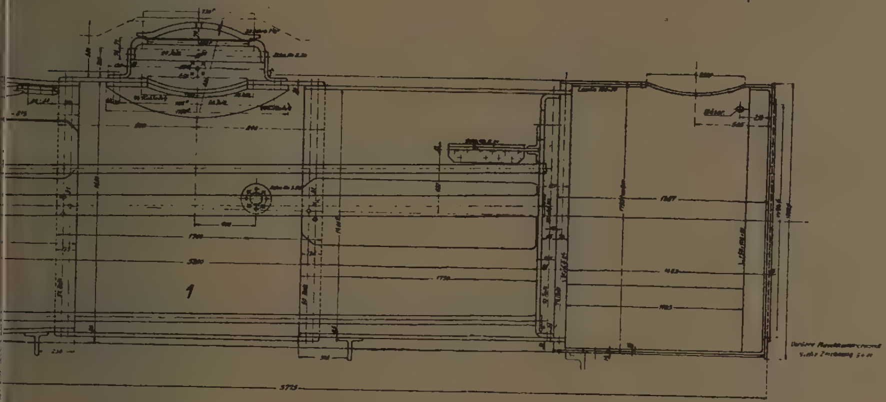
Fig. 3. — Boiler of Maffei turbine locomotive

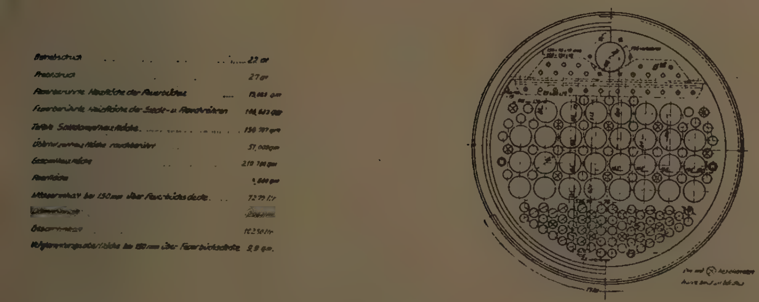
Legend:

Boiler pressure . . . .
Boiler pressure during test . . . .
Heating surface, inside firebox . . . .
Heating surface; inside water tubes and superheater tubes . . .
Total heating surface (saturated) . . . .
Superheating surface . . . .
Heating and superheating surface . . . .
Grate area . . . .
Water capacity, with 6 inches above crown of firebox. . . . . . .
Steam capacity . . . .
Total capacity . . . .
Evaporating surface, with 6 inches water above crown of firebox. . .

(5 3/64 — 5 7/16 inches) diameter.
1/64 — 2 13/64 inches) diameter.

Rivet hole 31 mm. (1 7/32 inch).
Rivet of 30 mm. (1 3/16 inch).
For longitudinal and cross seams.





sure of 22 kgr./cm² (312.9 lb. per sq. inch).

planation of German terms: Kupferstehbolzen = Copper staybolts. — Schaftdurchmesser = Diameter of body. — Anbohrung = Perforation. — Rauchrohre = Superheater tubes. — Siederohre = Water tubes. Nietloch = Rivet hole. — 30 pf Niet = 1 3/16 - inch rivet. — Für Länge- und Quernahte = For longitudinal and cross seams (rivets).

been considered the most important factors for designing.

The required high values could easily be obtained by using appropriate cross-sections in the horizontal tube superheater with threefold steam return, like the usual design of the Reichsbahn evolved from the flue and smoke box superheaters. For a long time the endeavour was made to proportion the heating surface to the steam output of the boiler in a simple manner by the number of elements connected in parallel. But the important question remained as to which zone is the most effective for the actual superheating process. It was undoubtedly desirable to extend further towards the firebox in order to utilise the high temperature gradient, but a limit was soon reached due to imperfection of the return bends and lack of maintenance. The return bends which were at first brought to within 300 mm. (11 13/16 inches) of the rear tube plate, and into which the superheater tubes were secured by a fine thread, soon burnt because they were not cooled sufficiently by the flow of steam, while the flow of heat from them to the tubes was impeded by the jointing material.

As a means of preventing this premature trouble on superheaters, the Schmidt Superheater Company recommended the retention of the dampers used originally with flue and smoke tube superheaters for the purpose of preventing overheating of the tubes when the locomotive was standing. But these dampers, which should be actuated from the regulator by means of an automatic steam cylinder, proved troublesome to maintain owing to their getting bent and interfering with access to the joints.

In the days of the Prussian-Hessian Railways the dampers were given up and it was preferred to place the return bends 600 mm. (1 ft. 11 5/8 in.) forward from the firebox. The damage to the tubes was certainly reduced, but at the same time the superheat fell to about 300 or 320° C. (572 or 608° F.). At the time when the only cylinder oil available was of inferior quality and low flash point, this lower superheat was undoubtedly very welcome, but as suitable oil became obtainable energetic steps were taken to improve the conditions.

One of the first moves was towards better manufacture of the return bends. They were stamped out of mild steel and joined to the tubes by autogeneous welding, and by this construction the above-mentioned defects were eliminated. The constructional methods of the American Superheater Company which soon after were introduced into Germany, proved even better. The return bends were fabricated out of the tubes themselves by special machinery cheaply and quickly. These bends were satisfactory and paved the way for once more advancing the superheater into the hot zone where it could best fulfil its purpose.

Exhaustive investigations have shewn that the distance of 400 mm. (1 ft. 3 3/4 in.), as now standard for the larger locomotive of the Reichsbahn, is satisfactory, and enables an adequate temperature to be attained; the degree of superheat was raised to 350° C. (662° F.).

Whilst the position of the rear return bends proved to be of the utmost importance for good and economic superheating, the Reichsbahn only gradually modified the forward bends between the halves of each unit, until they attained the shape and location now customary. For many years the original form of construction was adhered to, in which the superheater tubes were brought forward to the smoke box, and both halves were connected,

without a cap, by a pipe bend. No doubt the underlying idea was to make the heating surface of the superheater as large as possible, without, however, taking due account of the effectiveness of the surface, for which in most cases there was no longer an adequate temperature gradient. Therefore when more generous dimensioning of the boiler and a smaller specific loading led to a reduction of the flue gas temperature to the value now usual, it was found — originally in the 1 E freight locomotive, class G 12 — that the forward closed pair of tubes could be cut short somewhere in the zone where the gases have a temperature of 360 to 370° C. (680 to 698° F.). The superheating was not affected and there was a considerable saving in weight.

The result showed that not only was the heating surface of the front return bends wholly inefficient, but the re-cooling also, since the temperature gradient (50° C. [90° F.]) was obviously too small and the hot steam too sluggish in exchanging heat at 12 to 14 atmospheres (170.7 to 199.1 lb. per sq. inch). The only marked re-cooling occurred at the common partition wall in the header; in the meantime this has been overcome by division into two compartments for saturated steam and superheated steam respectively. Thus we arrive at the basis form of the present Schmidt large tube superheater, as used for boilers of 8 to 15 tons steam capacity per hour. Its adaptation to boilers of the largest sizes now in use or projected will be discussed later.

Reference may be made in connection with smoke tube superheaters, to a single test made with a chamber superheater of the Esslingen type, as shewn in figure 4. This does not fulfil the requirements of higher gas and steam velocities and strict co-ordination of their flow, and consequently permits temperatures of only about 280° C. (536° F.) to be reached. The test results confirm this. Chamber superheaters have not found any scope in Germany since they are all subject in some degree to the same shortcomings. Nevertheless, the same arrangement of steam pipe connection has been revived in the first high-pressure locomotives.

For small and short boilers it is desirable to have a superheater with smaller smoke tubes which would be more suitable to the shorter distance between the tube plates. This requirement gave rise to the Schmidt medium-tube superheater and a similar design by Borsig, which were tested in some service locomotives. The diameter of the smoke tube is reduced to 100 mm. (3 15/16 inches). A tube from the header is divided in the smoke box into two branches, which pass into the smoke tubes (see figs. 5 and 6) and after a single return are connected again to a common return pipe.

The same temperatures were attained as with the large-tube superheater, but a considerable pressure drop was manifested in the unduly small flow and return pipes.

The Borsig superheater similarly makes use of 100-mm. (3 15/16 inches) smoke tubes, but on the other hand the steam has a fourfold traverse as in the large-tube superheater, small pipes of 23/29 mm. (15/16 and 1 3/16 inches) being used; this design, likewise, shewed no advantages. Still smaller smoke tubes were used in the Schmidt small-tube superheater (see fig. 7), these being 64 to 70 mm. (2 1/2 to 2 3/4 inches), and occupying the whole tube space; it was tested in some tender locomotives. The chief object of this design is the avoidance of unequal flue-gas velocities in the smoke tubes and fire tubes, by using all or near-

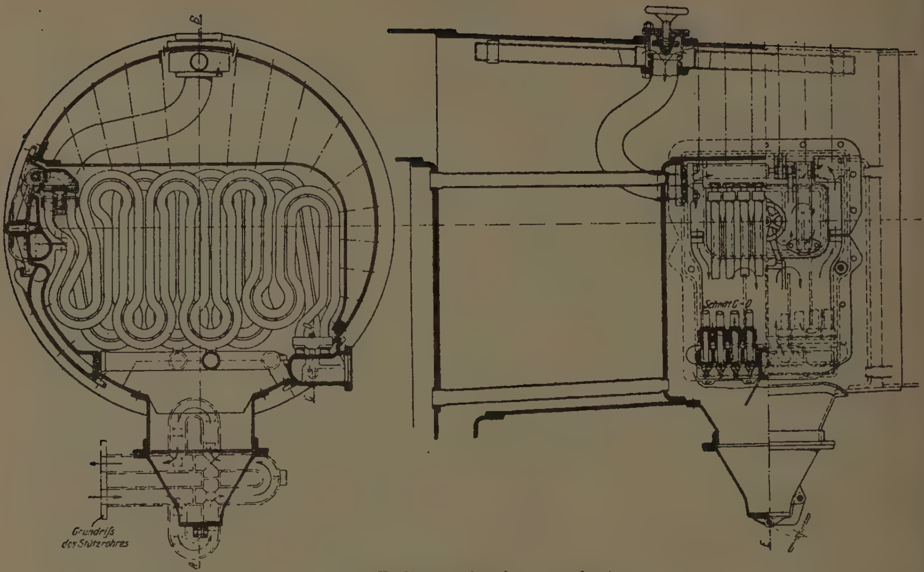


Fig. 4. — Esslingen chamber superheater.

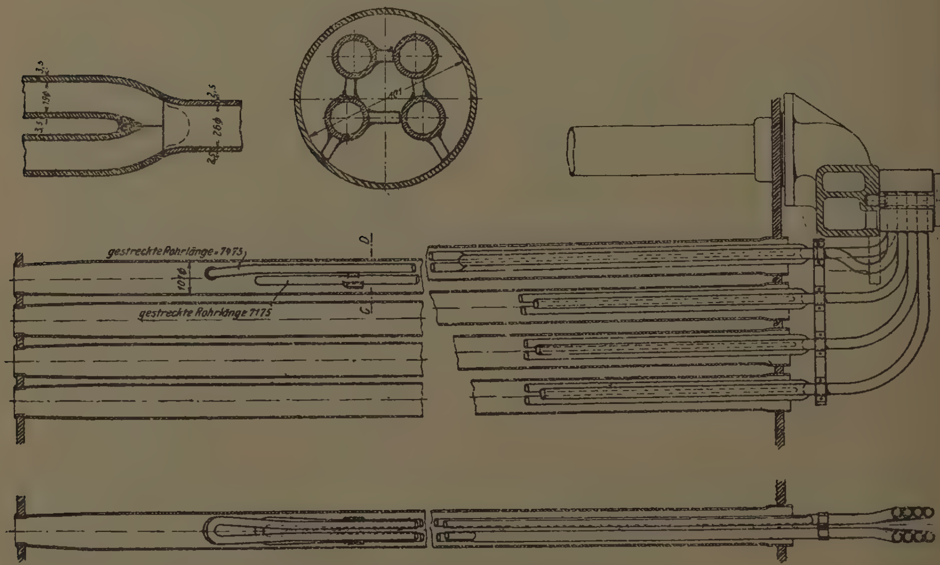


Fig. 5. — Schmidt medium-tube superheater.

Explanation of German terms in figs 4 and 5: Grundriss des Stützrohres = Plan of stay tube.
Gestreckte Rohrlänge = Length of tubes.

ly all of the tubes for superheating. Each smoke tube contains a single superheater loop of 19 mm. (3/4 inch) internal diameter pipe, but three or four loops are connected in series. The degree of superheat should accordingly be reached more quickly than with the large-tube superheater. A unit of this type is difficult to assemble and dismantle, and from the outset presents obvious drawbacks in operation. Further, the resistance to the passage of the gases of combustion was considerable even with the comparatively short boiler, and required the provision of a more powerful blast. A final reason for the decision of the Reichsbahn not to proceed further with this type, was that it became evident that a normal large-tube superheater in which the superheater pipes had been increased in thickness from 30/36 mm. to 30/38 mm. (from 1 3/16-1 7/16 inches to 1 3/16-1 1/2 inches) gave the full superheat more quickly, due to the equalising effect of the larger mass of iron.

In the main, therefore, attention was directed to improving the type of superheater that had already become the regulation pattern, with a view to attaining a further increase of superheat by simple means.

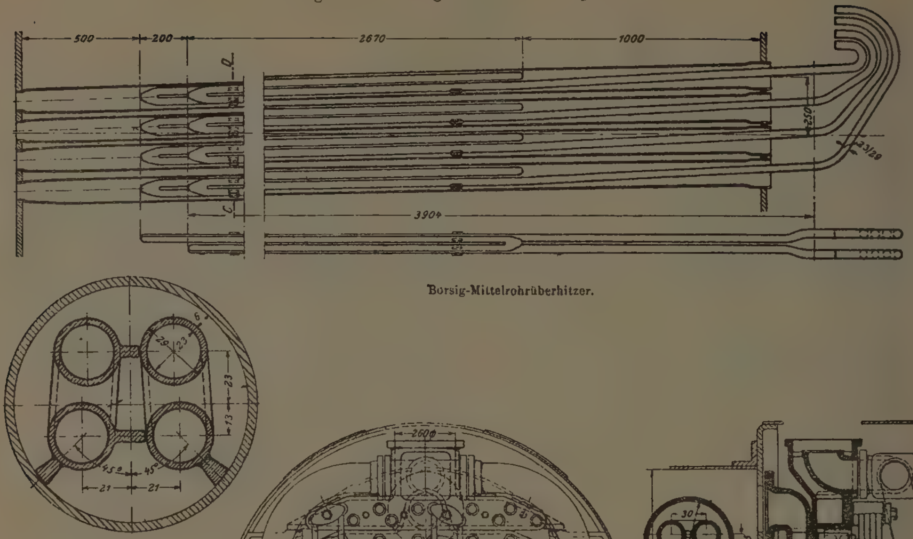
Tests were made on elements of the type proposed by Platz-Jakobsen. In this design the steam is led to and fro in two concentric pipes placed in a smoke tube of normal size, see figure 8. Recognising the considerable cooling at the border zone of the smoke tube due to water, the saturated steam was admitted to the outside jacket, and the hot steam was led back again in the centre of the hot stream of gas. But in this way the steam and gas flow in the same direction so that too little heat is extracted from the latter. An experiment with single units gave no better thermal effect than the regulation type, and there was, therefore, no reason to depart from the latter.

The same remarks apply to the construction shewn in figure 9; although this is based on correct theoretical ideas the results attained do not justify its cost. According to the scheme of the Evaporator Company the steam follows a spiral path to and fro in one pipe. The pipe is divided by a spiral partition into two ducts through which steam at widely different temperatures flows. The re-cooling, which on first thought would be feared from this arrangement, is small provided the temperature of the partition is maintained high enough to ensure a positive heat drop, by being intimately secured to the outer tube. Although the superheating is obtained with a certain reduction in weight, this is only obtained by using a considerably more expensive element.

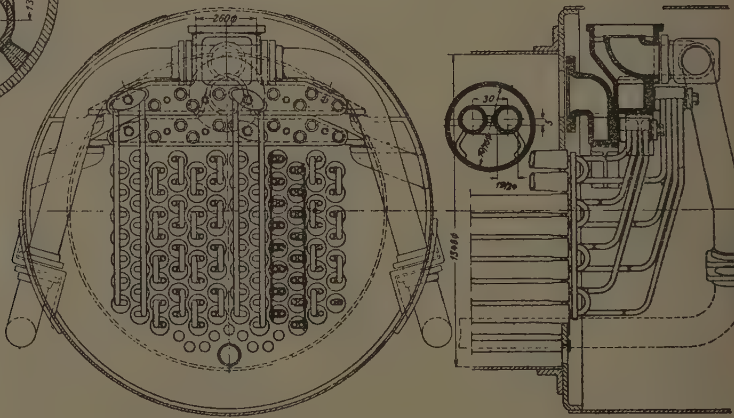
The same effect is aimed at in the designs of Dauner and Uddeholm (figs. 10 and 11), using spirals of tube placed in the hot gas zone. At the most, these designs offer a more intimate heat transfer due to the eddies produced in the gas stream, and a small saving in weight, but these advantages entail higher capital outlay and a more powerful blast.

Hence, there was not, in principle, any inducement to change the large-tube superheater in boilers of medium size. In fact by using it in various locomotives, especially those of large capacity (2 000 indicated horse-power and over) it was possible to collect information of general importance. The opportunity occurred of confirming the low superheat temperatures in the boiler of the 1-D-1 passenger locomotive of the former P 10 class, which has a heating surface of 220 m² (2 368 sq. feet), a distance of 5 800 mm. (19 ft. 3/8

Fig. 6. — Borsig medium-tube superheater.



Borsig-Mittelrohrüberhitzer.



Schmidtscher Kleinrohrüberhitzer.

Fig. 7. — Schmidt small-tube superheater.

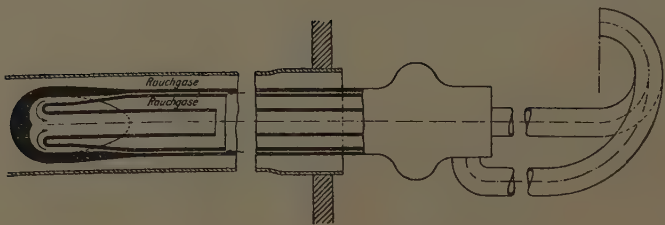


Fig. 8. — Platz-Jakobsen superheater.

in.) between tube plates, and in the first design a superheater heating surface of 82 m² (883 sq. ft.). The working temperatures were of the order of only 300 to 320°. Similar confirmation was obtained with the Saxony 1-D-1 locomotive of the XX H V class with the same tube length (280 to 300° C. (536 to 572° F.). In order to remedy this defect the number of superheater units was increased, experimentally, from 34 to 41, which, according to the usual view meant increasing the heating *surface* to 99 m² (1 066 sq. feet). As it was possible, however, that the fault

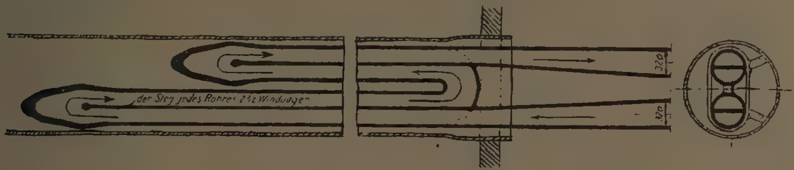


Fig. 9. — Deutsche Evaporator-Gesellschaft's superheater.

Fig. 10. — Dauner superheater.

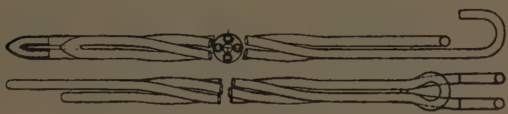


Fig. 11. — Uddeholm superheater.

might not be traceable to the steam side of the superheater, *i. e.*, to the use of too few elements, but to the gas side, *i. e.*, insufficient gas velocity and inadequate supply of heat, an experiment was also undertaken with the smoke tube diameter increased by 10 mm. (3/8 inch) to 135 mm. (5 5/16 inches) and only a slight alteration of the superheat heating surface (84.5 m² [910 sq. feet]).

The investigations showed that the enlargement of the steam side produced a small improvement in the superheating without affecting the unequal cooling of the gases in the smoke tubes and fire tubes, and occasioned a considerable increase in weight. The increased heat supply, on the other hand, gave good superheating with practically no alteration on the steam side; the better ratio of mean free cross-section to wall surface in the case of the larger smoke tubes was clearly to be regarded as the criterion for the gas velocity and heat emission. The result justified the practical application of this experience in the new designs, for which an extensive series of tests had provided the basis.

Accordingly the requirements laid down for obtaining increased superheating were:

1. The ratio $\frac{F_1}{F_2}$ to be as uniform as possible for every smoke tube and fire tube in a boiler.

F_1 = mean gas cross-section in tube.
F_2 = friction surface of walls.

2. Adherence to the best observed values for the actual value of $\frac{F_1}{F_2}$.

3. The dimensions of the superheater heating surface, *i. e.*, the number of elements, to be chosen according to the requirements of the steam side rather than the steam velocity.

Requirements 1 and 3 can be fulfilled without difficulty; as regards 2, the Reichsbahn endeavoured to work to a value of 1 : 400, based on the test results.

Along these lines it is possible to determine dimensions, as of the boiler, for example, without recourse to trial, so that one element of the locomotive that functions satisfactorily is obtained with certainty. In this way improvement of the whole locomotive is attained by the pèrfecting of the theoretical determination of designing data.

This knowledge was applied and incorporated in the general design and in the individual details, such as the superheater, of the large boiler shewn in figure 12, which represents the latest construction for the 2 C 1 standard express locomotive.

These locomotives were put into service as early as 1926. Although the boilers were built in accordance with the new research results they were capable of improvement in regard to heat utilisation and especially weight distribution. At the outset weight distribution and the general arrangement of these locomotives indicated that an unusually long boiler was desirable, taking into account the three pairs of coupled wheels of 2 000 mm. (6 ft. 6 3/4 in.) diameter with a very heavy firebox behind. But in the first design one hesitated for obvious reasons to make the tubes longer than usual. Hence for the first batch, a tube length of 5 800 mm. (19 ft. 3/8 in.) and a smoke-tube diameter of 135 mm. (5 5/16 inches) were employed, as tried in the P 10 boiler mentioned earlier, although this resulted in a smoke-box length of 3 800 mm. (12 ft. 5 5/8 in.). The weight distribution was just about satisfactory, though the back axle had an ample loading of 20 tons. In particular the design showed that the limit had been reached for the boiler, unless special measures were undertaken, in respect of further development, as for example an 8-coupled machine with large wheels and with a leading 4-wheeled bogie, the retention of the latter being undoubtedly desirable on account of the steadier running.

The adjustment of the centre of gravity by means of the combustion chamber was altogether out of the question, since, according to German ideas, it is undesirable from both operating and workshop aspects. An entirely new line was adopted, *viz.*, the use of tubes 6 800 mm. (22 ft. 3 23/32 in.) long.

Nothing was altered at the firebox end, the boiler body only was lengthened. Based on the three principles set out previously for superheater and boiler, the superheater pipes were 65/70 mm. (2 9/16-2 3/4 inches) and the smoke tubes 162 mm. (6 3/8 inches) and 4 mm. (5/32 inch) thick.

The diameter of the smoke tubes was based on the following considerations. If the superheater receives saturated steam of sufficient dryness, it is unnecessary for each element to re-enter twice,

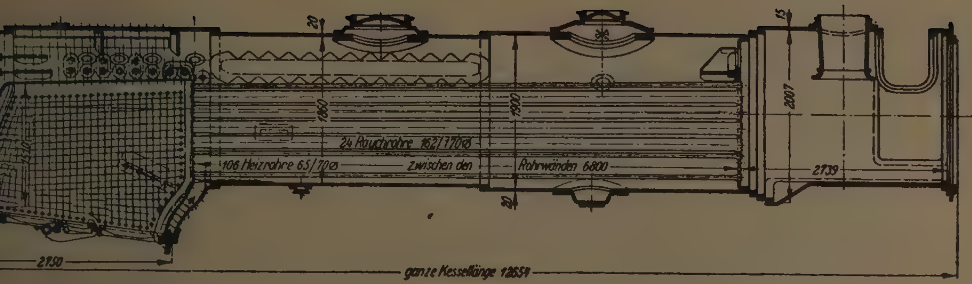


Fig. 12. — Experimental boiler with tubes 6.80 m. (22 ft. 3 23/32 in.) long.

Explanation of German terms: 24 Rauchrohre, etc... = 24 superheater tubes, diameter 162/170 mm. (6 25/64 — 6 45/64 inches). — 106 Heizrohre ,etc... = 106 smoke tubes, 65/70 mm. (2 9/16 — 2 3/4 inches). Zwischen... = Between tube plates: 6.800 m. (22 ft. 3 23/32 in.).

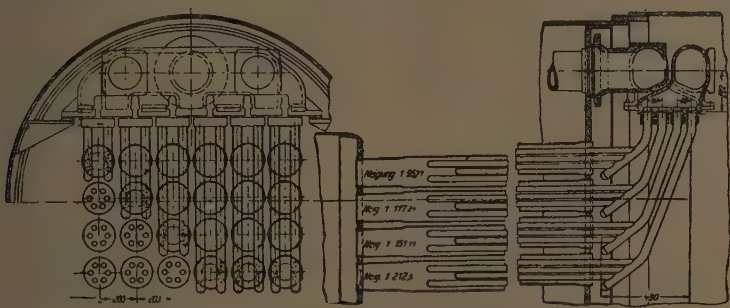
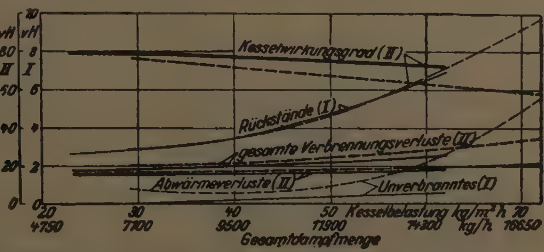


Fig. 13. — Arrangement of superheater on experimental boiler.

Explanation of German terms: Neigung = Inclination.

Fig. 14.

Stationary boiler tests.
Experimental boiler 2 C 1.
Locomotive No. 02010:
Tubelength 6.800 m. (22 ft. 3 $^{23}/_{32}$ in.).
Standard boiler 2 C 1.
Locomotive: tube length 5.800 m. (19 ft. $^{3}/_{8}$ in.).



Explanation of German terms: Abwärmeverluste = Heat losses. — Gesamtdampfmenge = Total weight of steam. — Gesamte Verbrennungsverluste = Total combustion losses. — Kesselbelastung = Boiler output. — Kesselwirkungsgrad = Boiler efficiency. — Rückstände = Residue. — Unverbranntes — Unburnt.

as in the Schmidt large-tube superheater; and further the cross-section of the large-tube did not appear to be sufficiently divided up by only four superheater tubes. A special distribution resulted from the introduction of six thin tubes of

23/29 mm. (15/16-1 3/16 inches) diameter and, falling back on the experience gained long ago with the Schmidt medium-tube superheater (see page 107), single entry was employed.

The novel superheater shewn in figure 13 resulted. To avoid the re-cooling of the superheated steam by the wet steam space, through the walls of the header, the two spaces are entirely separate in the new locomotives, whether fitted with a short boiler having a large-tube superheater or a long boiler, see figure 13, The connection pockets of the two headers alternate like interlocked fingers and have openings on the under side for connecting the superheater units. The flanges, between which are the fixing bolts of the superheater connecting pipes, are arranged so that the back one is fixed, but the front one is free to expand. The connections from the saturated and superheated steam headers pass downwards side by side in the approved manner. They are vertical at first and then bend towards the tube plate forming the headers for the three pipe loops in each smoke tube. The standard size of 39.5- 44.5 mm. (1 9/16-1 3/4 inches) has been used in order to avoid throttling on the wet side. The three superheater tubes are welded into the header pipe, one above the other, and the header extends slightly beyond the bottom junction and is sealed with a spherical cap welded on. This extension forms a pocket for the collection of the small quantities of rust and scale which often come away after a superheater has been in use for years.

The arrangement described has, in addition to its thermal superiority, two practical advantages over the usual large-tube superheater. It permits of thorough drainage after a water pressure test or when laying up, and gives good access to all parts behind the nest of pipes in the smoke-box so that it is even possible to blow out the fire tubes situated above the smoke tubes.

The number of superheater units was fixed at 24, since that gave the desired steam velocity of 12 to 16 m. (39.4 to 52.5 feet) per second.

The practical advantages of this new superheater construction can now be seen clearly in the fact that whereas with the above-mentioned steam velocity, the large-tube superheater provided 100 m² (1 076 sq. feet) of heating surface, the new superheater has only 84m² (904 sq. feet) or 16 % less with the same efficiency.

Another appreciable advantage is that the bare weight of the new boiler compared with that of the former regulation short boiler is 800 kgr. (1 700 lb.) less, at 35.7 t. (35.1 Engl. tons), whilst the service weight is 450 kgr. (990 lb.) greater, due to the water space being 1.25 m³ (44 c. ft.) larger. The comparative particulars of the two boilers are given in the table, figure 2. The increase in the water surface serves a valuable purpose, because with an evaporation of 60 kgr./m²/h. (12.3 lb. per sq. foot per hour) it was possible to reduce the average steam velocity to 3.25 m. (10.66 feet) per second and thereby ensure that dry saturated steam entered the superheater. This is of the greatest importance and is essential if the superheater is to perform its proper function and not act merely as a steam drier.

In figures 14 to 18 are summarised the results of the investigations made with the locomotive on the test plant. The efficiency of the new boiler falls very gradually from 78.5 % to 72 %. The corresponding curves for the regulation boiler have been inserted for comparison. They show that improvement had been effected on practically every figure.

The tests showed that the advantages

aimed at in the design of the boiler had certainly been achieved. In regard to mechanical strength, the new boiler has so far behaved no differently to other well-tried designs. All the new 2 C 1 locomotives, whether of heavy or light type, are

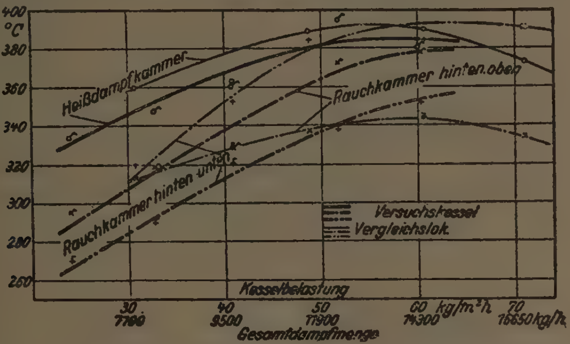


Fig. 15. — Temperatures in stationary tests.

Explanation of German terms: Heissdampfkammer = Superheater steam compartment. — Rauchkammer hinten (oben) = Smoke box bottom (top). — Vergleichslok = Comparison locomotive. — Versuchskessel = Experimental boiler. — Kesselbelastung = Boiler output. — Gesamtdampfmenge = Total weight of steam.

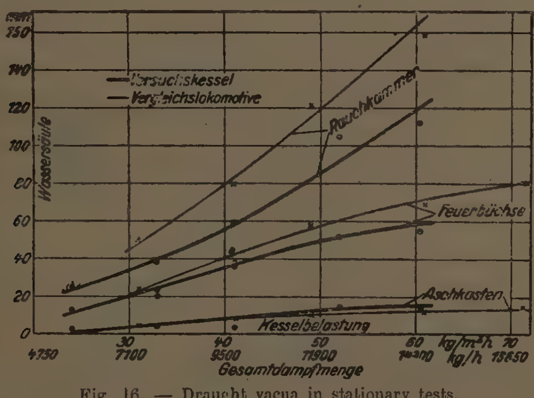


Fig 16. — Draught vacua in stationary tests.

Explanation of German terms: Aschkasten = Ashpan. — Feuerbüchse = Firebox. Wassersaüle = Column water.

being built with tubes 6 800 mm. (22 ft. 3 23/32 in.) long in view of the satisfaction experienced.

In the same way all boilers for the standard locomotives, as well as those for the lighter types, have been designed with a smoke tube diameter of 110/118 mm. (4 3/8- 4 5/8 inches). This has resulted in the attainment of what was always considered doubly difficult with small units,

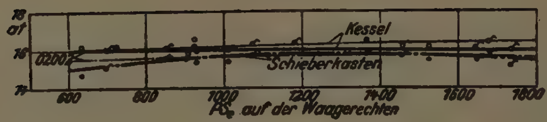


Fig. 17. — Steam chest pressure as a function of load on boiler.

——·—— Experimental boiler.
—— — —— Comparison locomotive.

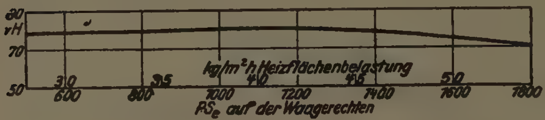
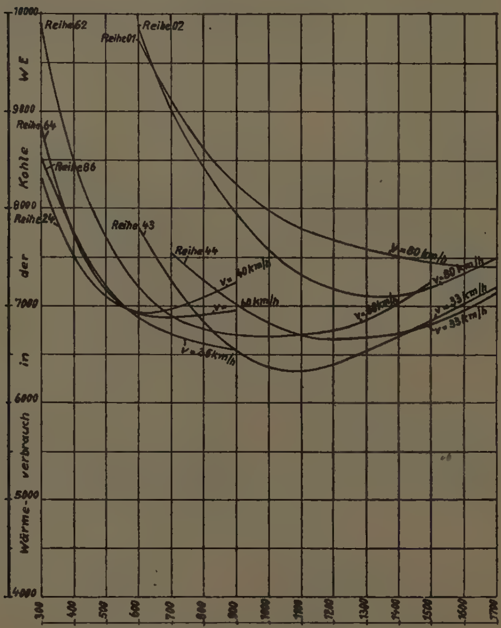


Fig. 18. — Boiler efficiency of experimental boiler on running tests. (v = about 80 km. [50 miles]).



Effective H. P. at drawbar hook.

Fig. 19. — Heat consumption of standard locomotives.

Explanation of German terms in figs 17 to 19: At = kgr. per cm². — Heizflächenbelastung = Output of heating surface. — PSe auf der Wagerechten = Effective H. P. on the level. — Reihe = Series. — Schieberkasten = Valve chest. — Wärmeverbrauch in der Kohle = Heat consumption in coal. — W E = Thermal units. — Zughakenleistung = Power developed at drawbar hook.

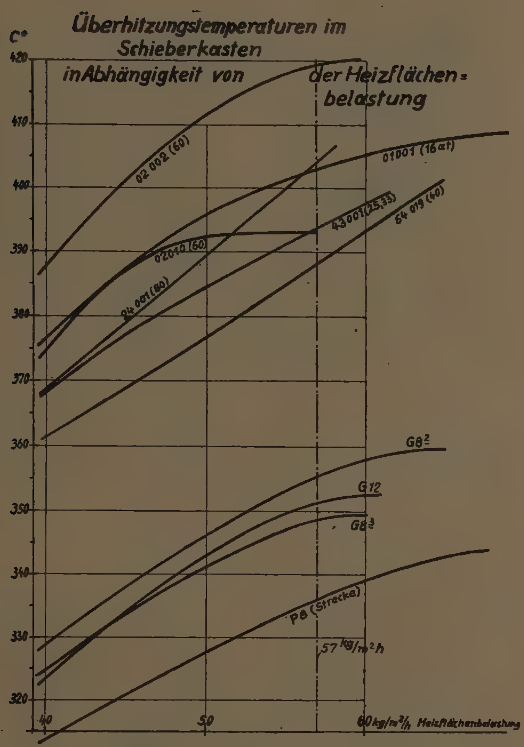


Fig. 20. — Superheat temperatures in steam chest as a function of specific output of heating surface.

Explanation of German terms: Überhitzungstemperaturen = Superheat temperatures. Strecke = On the line.

namely, a very low coal consumption. The actual values of the consumption are given in figure 19. In all of these locomotives without exception a high degree of superheat has become possible with a low cost of construction. The range of superheat obtained is shewn in figure 20; most of the locomotives reach the 400° C. (752° F.) region. It should be recognised that with the use of higher pressure steam, as *e. g.* in the 60-atmosphere (850 lb. per sq. inch) Schmidt locomotive, the superheat likewise can and should be taken higher, if it is desired to be sure of working above the saturation curve. Hence in this case the degree of superheat was taken up to 440° C. (820° F.) without hesitation. This experience agrees completely with what has already been confirmed in stationary plants, that one

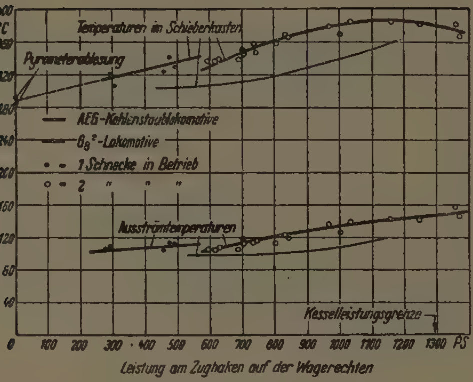


Fig. 21. — Steam temperatures at mean speed of 35 km. (21.7 miles) per hour.

Explanation of German terms: Temperaturen im Schieberkasten = Temperatures in valve chest. — Pyrometerablesung = Pyrometer readings. — A. E. G. Kohlenstaublokomotive = A. E. G. pulverised-coal burning locomotive. — Schnecke in Betrieb = Worm gear in service. — Ausströmtemperaturen = Exhaust temperatures. — Kesselleistungsgrenze = Limit of load on boiler. — Leistung am Zughaken auf der Wagerechten = Power developed at drawbar hook on the level.

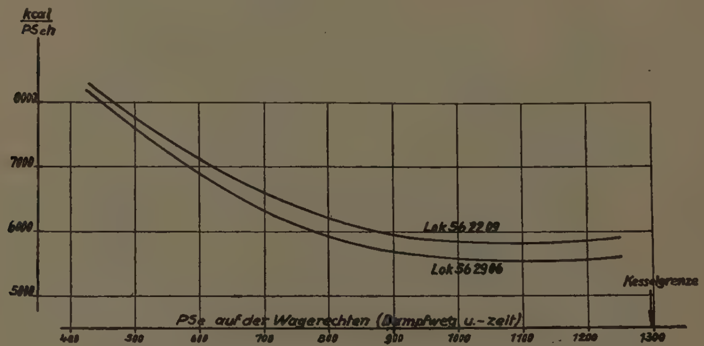


Fig. 22. — Heat consumption (in the steam) from 0° C, per effective horse-power-hour — including feed pump — at mean speed of approx. 35 km. (21.7 miles) per hour, and varying degrees of superheat.

Explanation of German terms: PSe auf der Wagerechten (Dampfweg u. -Zeit) = Effective H. P. developed on the level (distance and time run under pressure). — Kesselgrenze = Boiler limit.

can increase the temperature with the pressure without difficulties arising; lubrication is not adversely affected.

It is difficult to ascertain to what extent the economies obtained in the new locomotives are due to the high superheat, since many different features contributed to the final result. Some indication is afforded by the figures secured on test runs with one of the first G8² lo-

comotives rebuilt for pulverised fuel firing — a type already known. The special feature of this form of firing, that a part of the combustion occurs in the smoke tubes, renders it possible to obtain higher steam temperatures without altering the superheater. Whereas the grate fired locomotive had temperatures ranging from 300° C. (572° F.) at small loads up to 360° C. (680° F.) at greater outputs, with pulverised fuel the values were 330° and 385° C. (626° and 725° F.). The resulting saving in heat consumption (in steam) from 0° C. (32° F.) per draw-bar horse-power, is about 5 % between 600 and 1 200 H. P.

The use of highly superheated steam in the cylinders leads in many cases to the exhaust temperature at considerable loads also lying in the region of superheating. It ranges between 150° and 180° C. (302° and 356° F.). It is interesting to record that figure 19 agrees with the facts ascertained by Schmidt, *viz.*: that high exhaust temperatures of this kind do not signify any loss, but that the saving due to the high initial temperature preponderates. The chief reason for this is that for a given pressure the quantity of heat in unit volume of steam decreases as the temperature increases, up to a certain temperature. The limit would just occur with 150° to 180° C. (302° to 356° F.) discharge temperature. Figure 23 shows that in the majority of the new locomotives the range of favourable consumption corresponds with high initial temperatures.

Ever since locomotives have been equipped with superheaters the isolating device in the steam supply from the boiler to the engine has taken the form in Germany of a regulator valve with a pneumatic coupling between the rod and the main valve. The features required in the control element were :

Easy operation combined with fine regulation of the steam supply; passages of large cross-section to avoid wasteful throttling; low maintenance charges. From the beginning the regulator has been developed as a wet-steam regulator for the reason that it is not then subjected to the high temperature, and the large steam-tight surfaces are preserved from distortion. Owing to the small space in the dome of the high boilers on the standard locomotives, the working out of a suitable regulator was particularly difficult.

A regulator of the type in question, of the Wagner design, is shewn in figure 24. The regulator rod is connected only to a small pilot valve. When the valve is lifted a difference of pressure is produced between the two sides of the main valve and this causes the latter to float in the steam in a position which is determined by the pilot valve. It is all the more difficult to obtain reliable operation of a regulator for the large boilers of the standard locomotives, on account of the steam passages being made very large (200 mm. 7 7/8 inches) with a view to a minimum pressure drop between the boiler and the slide valves.

Perfect utilisation of the energy requires that precautions shall be taken to maintain the maximum pressure within narrow limits, which means that the safety valve must not blow off prematurely, and on the other hand it must close immediately the normal pressure is regained. At the same time the great evaporative capacities of large boilers render it essential that considerable volumes of steam should be discharged when necessary, as in the case of a sudden reduction of load. Hence it became necessary to

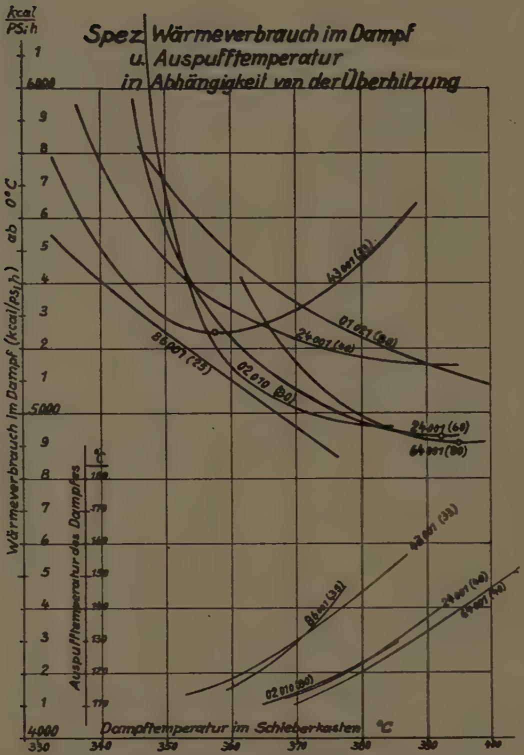


Fig. 23. — Specific heat consumption in steam, and exhaust temperature as functions of the superheat.

Explanation of German terms: Wärmeverbrauch im Dampf (k cal/PSi : h) = Heat consumption in steam (Kgr.-calories/Ind. horse power-hour). — Auspufftemperatur des Dampfes = Exhaust temperature of steam. — Dampftemperatur im Schieberkasten = Steam temperature in valve chest.

resort to using high lift valves. After testing a great many different valves the Ackerman valve shewn in figure 25 was adopted as the standard pattern.

Whereas in other high-lift valves the steam has to deviate twice through an angle of 90°, in this valve it changes direction only twice through an angle of 45°; this considerably reduces the resistance to the passage of the steam. Due to this and to proper dimensioning of the passages to meet the steam flow requirements, it was possible to obtain a high discharge capacity with a relatively small cross-section. Dynamic lifting action by the steam jet is brought into play to ensure that the valve responds at once to the smallest excess pressure; to this end there is an auxiliary lifting face of conical form adjoining the valve face proper. The

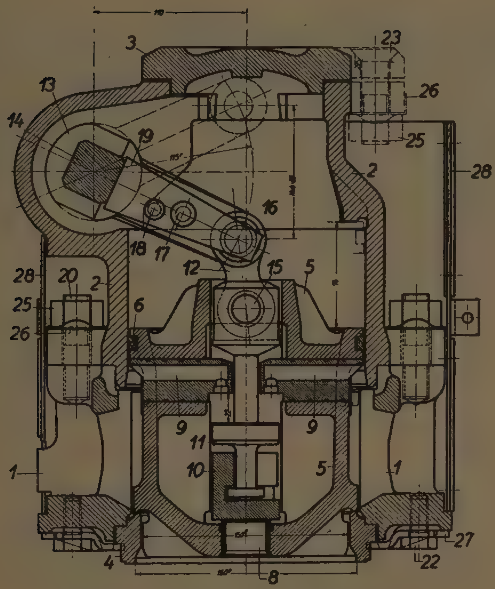


Fig. 24. — Schmidt and Wagner regulator.

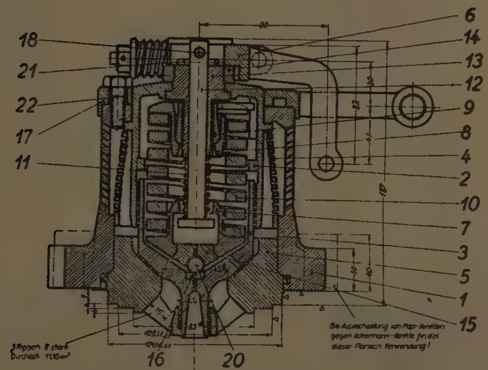


Fig. 25. — Ackermann boiler safety valve.

loading spring is enclosed in a chamber in which partially spent steam collects; in the normal position of a relief valve this steam can escape. If, while the valve is still blowing off, the pressure has fallen to the prescribed boiler pressure, the

valve can be made to close immediately if the dynamic pressure is neutralised by closing the above-mentioned relief valve and thus building up a back pressure in the spring chamber. For this purpose a second pull line is provided for the « adjustable auxiliary » valve, in addition to that for the lever that is used for testing the valve.

Many years of satisfactory experience with that type led to the continued retention of piston valves with internal admission, and Walschaerts valve motion with reversing link and stirrup rod, for distributing the steam to the cylinders. Attention has been given to the improvement of every detail of the steam distribution, and one of the chief tasks, amongst others, was the adaptation of existing valve gear to the increased temperatures.

In Germany it is the rule to base the cylinder dimensions on a 20 to 30 % cut-off in normal service, *i. e.*, early cut-off and economical steam expansion, but to give the cylinder the greatest possible starting power, the valve gear then cutting off at 80 to 85 %. Hence the cylinders are relatively large, but within the usual range of loading they permit full utilisation of the steam. In order that the requisite use might also be made of the full boiler pressure it was necessary to give the valves suitable dimensions. It was possible to do this in the case of the series of standard locomotives by using two sizes of valves. A diameter of 220 mm. (8 11/16 inches) was used for the smaller locomotives with cylinders less than 500 mm. (19 11/16 inches) and the larger size with 300 mm. (11 13/16 inches) diameter was employed for cylinders over 500 mm. Even though throttling at admission theoretically denotes no loss, it would nevertheless give an unfavourable utilisation of the available cylinder volume; or else necessitate running with a later cut-off than is the case with correct valve design, in order to obtain the required diagram area.

The valve bodies move in special sleeves. During the last ten years valve sleeves with a slight taper had been used and pressed in so that the press fit gave the necessary steam tightness. But these had not been satisfactory. Unless the tapering was done with extreme care without turning down the steel, the sleeves were usually tight under the water pressure test, but not against hot steam. Therefore, in standardising the new locomotives, recourse was had to the loose sleeves that had been used earlier and proved more successful. They fit into the admission chamber with a parallel metallic surface that can easily be ground and are made tight against the escape of steam by an elastic copper-asbestos ring. The exhaust boxes which are bolted on the ends of the valve chamber press the packing rings against the joint surfaces of the sleeve and cylinder, equalise small unevenness by virtue of their elasticity, and press the sleeves against the inner metallic joint surface. An example of the valve is shewn in figure 26.

Reference may be made in this connection to the working out of the valve motion for the multi-cylinder engines, particularly the three-cylinder simple freight locomotive type 1 E, series 44. A separate valve motion has been arranged for each cylinder in order to obtain accurate steam distribution in all three cylinders. This obviates the defect of link transmission from the outer cylinders, which, owing to the accumulated « play » has quite a noticeable effect on the steam distribution. The valve motion for the inside line which resulted in shewn in figure 27. An

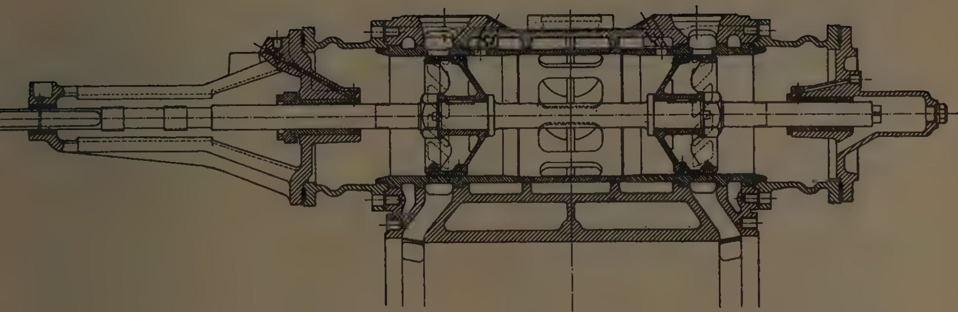


Fig. 26. — Piston valve.

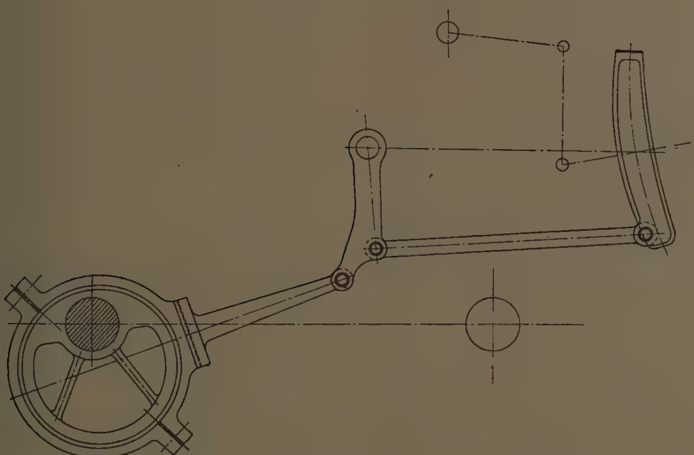


Fig. 27. — Eccentric drive, with intermediate lever for inner valve motion of series 44 locomotives.

eccentric actuates the links through an intermediate lever which enables the crank-axle to be cleared.

The question of the cylinder arrangement for large superheater locomotives, *i. e.*, whether compound or simple expansion, was dealt with for the first time, in connection with the new standard locomotives, on a strictly comparative basis, by building exactly similar engines differing only in this respect. Of the first 2 C 1 express locomotives of the standard series ten were built as four-cylinder compounds and ten as two-cylinder simple expansion units.

The cylinder ratio was chosen with reference to the suitability of the engine for working on the contours usual in

lowland country, with gradients of about 5 per 1 000 (1 in 200), and was fixed at 1 to 2.45. This ensured the possibility of an increase in the output of the low-pressure cylinder, with advancing cut-off on gradients, by reason of the increased pressure in the receiver. The heat consumption figures given in figure 19 from a comparison of both types, show that above an output of about 750 effective horsepower, the compound engine is better than the two-cylinder simple by a maximum of 6 %, while at the much more frequent smaller loads the twin-simple is the more economical. The small difference in fuel consumption scarcely justifies the higher initial and workshop costs of the four-cylinder compound units.

The comparison in the case of freight locomotives, type 1 E, of series 43 and 44, was similar. The last of these machines were built as three-cylinder simple engines and these proved inferior to the two-cylinder engine from the thermal point of view. This was due to the inherently larger amount of energy absorbed in the multi-cylinder motions, and further, to the great heat losses in the cylinders which is a natural result of the large ratio between their surface and volume. As a consequence the consumption curve of the three-cylinder engine rises with decreasing load, a circumstance quite in accord with the fact that the greater portion of the losses in the motion, due to piston, valve and stuffing-box friction, remains constant and, therefore, show more prominently at small than at large loads.

Hence the two-cylinder arrangement offered so many advantages for both the classes 2 C 1 and 1 E over the costlier and more complicated multi-cylinder construction that it was adopted as standard for the future, particularly as it is convenient from the constructional side as well. A simplification of this kind must be looked upon as a decided improvement of the locomotive from the technical operating standpoint, even though it entails a slight sacrifice in thermal efficiency as compared, for example, with a compound engine.

Since the conclusion of the above-mentioned tests in 1927, only two-cylinder simple-expansion engines have been built for the Deutsche Reichsbahn. The modern application of high superheat has, of course, to be taken into account in designing the cylinders. In order still further to improve steam economy the clearance has almost without exception been brought down to 9 or 10 %, which is considerably smaller than was formerly the rule. This implied omitting the form of bye-pass valve previously in vogue, since it contributed largely to increasing the clearance. It has, therefore, been developed on the lines indicated in figure 28. Two valves are arranged immediately above the admission ports of the valve liner of such a size that the drawing in of fresh air is minimised, and in this way the connecting passage no longer forms clearance space on the other side of the cylinder. But at the same time the compression can be kept within the limits appropriate for cushioning action. As shewn by the overall consumption figures, the reduction of the clearance space has contributed greatly to improved steam economy in the cylinders. This naturally calls for very careful construction and testing of the admission and exhaust laps if loops in the diagram are to be avoided at early cutt-offs.

As opposed to earlier designs the piston rods are made of the same size on both sides of the piston, in order to minimise as much as possible wearing of the cylin-

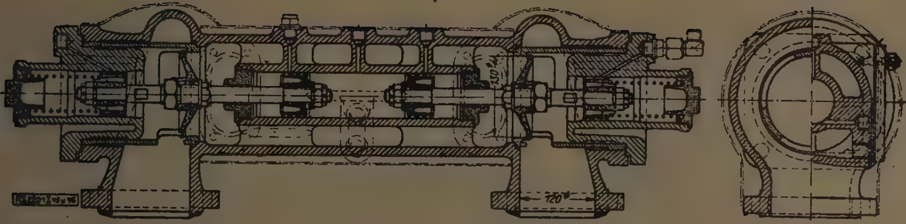


Fig. 28. — Air controlled bye-pass with angle valves.

der and piston rings. Previous experience with rods having the front end of smaller diameter showed that the piston still sagged too much and thereby gave rise to the wear previously mentioned. Moreover, the front guide bush also was unequally worn, due to the rod bending. In addition, the bearing surface of this bush was not big enough. The front guide bush is now generally constructed in accordance with figure 29, so that it can adjust itself longitudinally to the alignment of the piston rod.

The introduction of a uniform diameter for the rods led to a considerable economy in the number of sizes of stuffing-box. It became possible to work without difficulty to 100 mm. (3 15/16 inches) as a general rule for all main line locomotives of the standard range with considerable piston pressures, and to use 80 mm. (3 1/8 inches) for the lighter locomotives. Hence in the main only two patterns of packing glands are necessary. The only additional size was for the isolated case of the two-cylinder 1 E engines of series 43 for which a piston rod diameter of 110 mm. (4 3/8 inches) was unavoidable in view of the rod loading of approximately 58 t. (57.1 Engl. tons).

Years of experience has shewn the superiority for high superheat of cast-iron « cellular » stuffing-boxes with combined packing and labyrinth glands, as compared with glands having white metal rings.

Tests were carried out on four designs manufactured by :

1. Messrs. Sack & Kiesselbach, Düsseldorf.
2. — V. d. Osten & Kreisinger, Hamburg.
3. — Huhn, Berlin.
4. — Klauber & Simon, Dresden.

The original designs differed not only in the construction of the packing rings but also in their proportions and in the design of the containing box. By combining their best features, the « split-cellular » form of the Reichsbahn, as shewn in figure 30, was arrived at. The two halves are dowelled and secured together by four bolts so that they can be ground up to a good metallic fit on the cylinder cover. Each contains three cells of standard dimensions; the packing rings are interchangeable, so that only a few spare rings need to be held in stock at each depot.

An important question connected with increase of superheat temperature is the problem of lubricating the parts that are exposed to steam. Side by side with the selection of a suitable oil, the development of suitable lubricating devices, in particular, has been the subject of lengthy investigation. The same oil is still used as was introduced when the superheat was increased from 280° to 350° C. (536° to 662° F.). Its vaporisation temperature

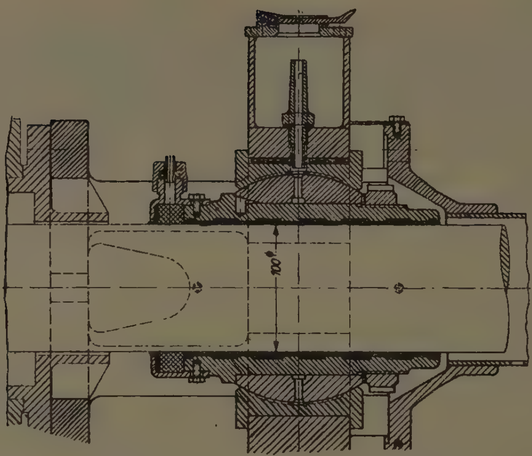


Fig. 29. — Forward piston rod guide bush.

is about 400° C. (752° F.) and higher when under pressure, so that it will still adhere to the surfaces. It is stipulated that the flash point in an open vessel shall be 300° C. (572° F.) but experience shows that this is not of so much importance as the vaporisation point, since the flash point only becomes a consideration when there is a possibility of the high-temperature oil having a sufficient air supply to bring about its combustion.

The specification calls for the following:

Specific gravity at 20° C. (68° F.)	0.95.
Viscosity :	
Engler number at 100° C. (212° F.)	over 5
Bituminous matter	under 0.1 %
Acid value	0.7
Ash	under 0.1 %
Water.	under 0.2 %

The temperatures of the cylinder walls and the piston correspond to the mean pressure and are, therefore, considerably lower than that in the steam chest. Correspondingly it is comparatively easy to ensure good lubrication in the cylinder, but not for the valves. Up to 300° C.

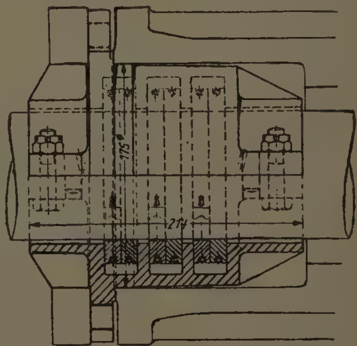


Fig. 30. — Cast-iron packing gland for 100 mm. $\left(3\frac{15}{16}\text{ inches}\right)$ diameter rod.

(572° F.) broad spring rings could be used provided the lubrication was generous. This however resulted in very excessive lubrication and consequent foul-

ing and carbonisation of the steam ports, cylinders and pistons. In dealing with higher tmperatures the endeavour was at first made to use valve heads without rings by specifying exactly the tolerances and grinding temperatures, but at that time this could not be put into practice as the technique of grinding and measuring was not able to meet these requirements. To overcome excessive lubrication it was necessary to decide first of all to give up supplementary lubrication in the form of admixture to the steam. In fact the oil should reach the moving surfaces directly as drops under pressure. At present, following various unsuccessful experiments with valves without rings, as already mentioned, valves with narrow spring rings of the Davy-Robertson type have been introduced.

In the present standard design each of the admission and exhaust edges is made tight by two rings. With the introduction of better means of introducing the oil the difficulties disappeared. At one time rams were used almost exclusively for this purpose, but now these have been given up in favour of oil pumps which enable the resistance of the connecting pipes to be overcome more easily than was possible with the slow movement of the ram plunger. Nevertheless, the development of absolutely reliable pumps suitable for working against a high back pressure occupied a considerable time. Experience indicated that such pumps must be capable of delivering reliably against a pressure of 200 atmospheres (2 840 lb. per sq. inch), a performance of which most of the known types were not capable. The high pressure is not required simply to overcome the resistance of the clean piping, since 25 to 50 atmospheres (355 to 710 lb. per sq. inch) at most would suffice if no back pressure existed. Immediately carbonisation occurs the pressure required increases considerably, and diminution of the pipe section can actually occur in the vinicity of the hot steam chest.

Therefore, the maximum pressure must be fixed at 200 atmospheres (2 840 lb.), in which case an ample volume will be delivered even against a resistance equivalent to 100 to 150 atmospheres (1 420 to 2 160 lb. per sq. inch). As the result of many tests a Bosch pump of the design shewn in figure 31 has been adopted and has been found satisfactory.

Each element of the pump consists of two pistons for delivery and control respectively, driven by a cam plate so that they make two strokes for each revolution of the plate and thereby feed two connections. The elements are grouped round the driving spindle and can be withdrawn for inspection complete with the control and pump pistons. A range of indicator glasses of the type shewn in figure 32 is fitted close to the pump in each of the feed pipes to the parts that are running steam and these enable the proper feed to be checked.

Experience showed that the design of the oil pipes and the method of introducing the oil are also of the greatest importance especially in the steam chest, if the pump is situated at a distance from the part to be lubricated. As it had to be fitted in the cab in order to permit constant regulation of the feed to each point, some of the pipes were as much as 10 m. (32 ft. 9 3/4 in.) long. The pipes were run close alongside the boiler in order to keep them warm and to prevent the oil congealing when the air temperature was low. Whereas originally 7-mm. (9/32 inch) pipes were used, in the newest locomotives it was necessary to go back to 4 mm. (5/32 inch) in order to guard against the separation in the form of bubbles of air that are unavoidably retained in the oil. This reduction in section appeared to

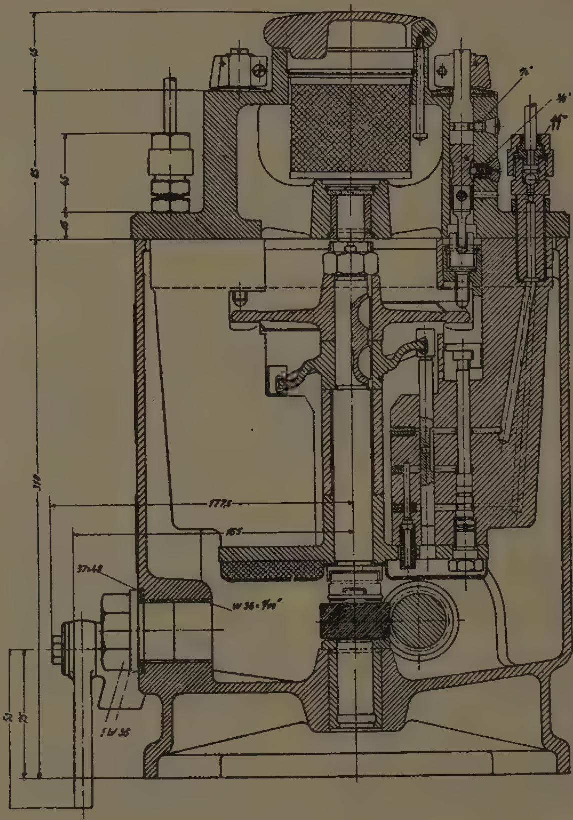


Fig. 31. — Bosch type oil pump. (Reichsbahn).

have scarcely any appreciable influence on the resistance in clean pipes. The determining factor on this point is always the carbonisation that may sometimes occur at the hot end of the pipes.

When the oil has become warm it gets very thin and is inclined to run out of the pipes. Moreover, the surprising fact was ascertained from some tests that the oil contained considerably more air than had been assumed; this air collects into large bubbles in the pipes. As soon as the regulator is shut off and the pressure in the steam chest disappears, the bubbles expand and force out suddenly a portion of the contents of the pipes. This results in the flow of oil being interrupted for a run of up to 100 km. (62 miles) and seldom less than 30 km. (18.6 miles). With a view to economy, the provision of

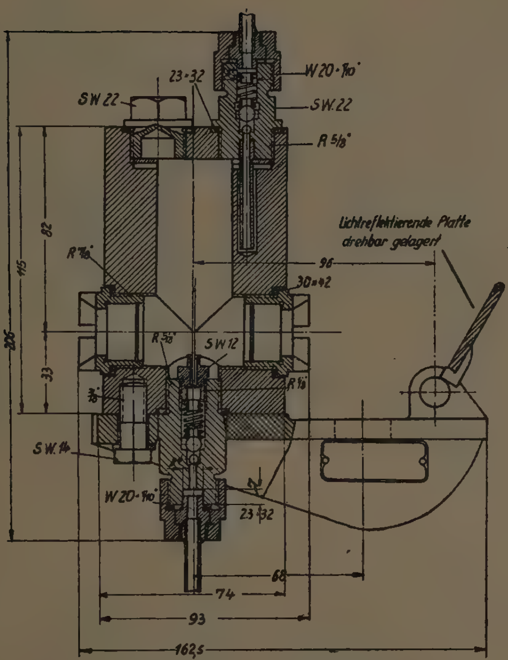


Fig. 32. — Section of drip indicator.

Explanation of German terms: Lichtreflektierende Platte drehbar gelagert = Pivot mounted reflector plate.

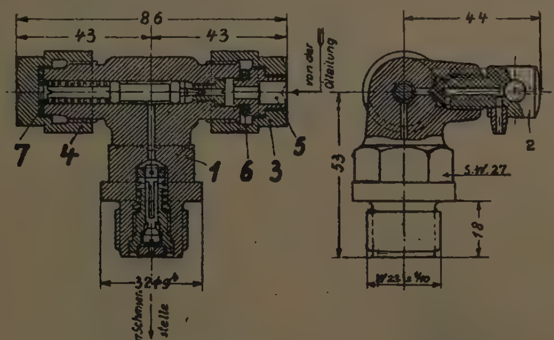


Fig. 33. — Woerner oil check valve.

Explanation of German terms: Zur Schmierstelle = To point to be oiled.
Von der Ölleitung = From oilpipe.

check valves, near the lubricating points was, therefore, called for. As the result of comprehensive tests the Woerner valve shown in figure 33 was singled out for extensive use. The difficulties experienced were mainly in connection with steam and air flowing back along the pipes which had been emptied by the action of air bubbles. The non-return valve in each pipe close to the point of feed gives a free passage to pressure oil from the pump but prevents the hot steam entering the pipes.

The figures of oil consumption testify to the successful development of a system of lubrication which is more adequate and reliable at high temperatures and also more economical. Thus the 2 C 1 locomotives of series O 1 now use about 4 kgr. of high-temperature oil per 1 000 km. (14.2 lb. per 1 000 miles), while in individual cases of particularly good driving the figure is as low as 2.3 kgr. (8.15 lb.).

In addition to the systematic use of exhaust steam preheaters, which were specially attractive by reason of the great saving they effected for a small outlay, exhaust gas preheaters of several designs were tested. Amongst preheaters of the straight exhaust gas type, mention may be made of the Werle, figure 34, which consists of a nest of water tubes situated across the upper part of the smoke box and connected to headers. With this arrangement it is difficult to follow out strictly the contra-flow principle that is desirable, and the unequal heating of the tubes causes difficulty in keeping them tight in the header walls. Neither is it an easy matter to bring the whole of the flue gases into intimate contact with the tubes. On the other hand, the design lends itself to ease of erection and dismantling. The sluggish flow of the gases is reflected in the performance. Accurate tests on the preheater when working under steady conditions in conjunction with an exhaust steam preheater, which it was intended should complete this part of the equipment, showed a saving of only 2 to 3 %, and even this figure could not be confirmed under service conditions. As it also proved very difficult to keep the tubes free from rust on the outside and, owing to their U shape, from scale on the inside, the design was dropped.

The mixed type of preheater of the Borsig Locomotive Works shown in figure 35 was tested. Its design is based on the fact that transfer of heat from the combustion gases is increased by wetting the heating surface. In these tests also, an exhaust steam preheater was employed in addition, for the reason that to obtain the same result with an exhaust gas preheater alone would have necessitated too large a heating surface. The heating surface of the preheater is impinged upon by a mixture of exhaust steam and flue gases. The apparatus — which is accessible but unsightly — consists of a cylindrical vessel placed above the smoke box in the position usually occupied by the chimney. It is pierced by a number of vertical brass tubes, which in the aggregate are equivalent to the chimney. Below the tubes the blast pipe terminates in a crown of nozzles. The feed water flows comparatively slowly through the inside of the vessel outside the chimney tubes, on the contra-flow principle.

The heating surface is very small in this arrangement and high values of heat transfer are obtained. It was not possible, however, to raise to more than 125° C. (207° F.) the water which left the exhaust steam heater at 95° to 100° C. (203° to 212° F.) so that the saving in terms of fuel was again in the neighbourhood of

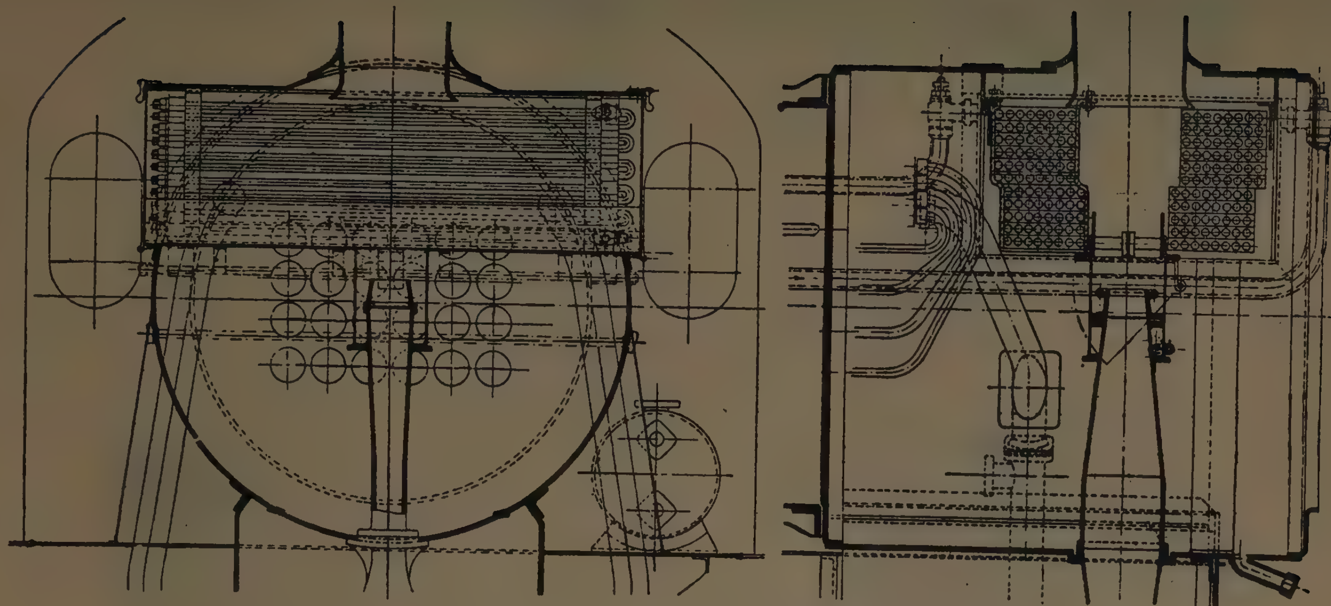


Fig. 34. — Werle exhaust gas preheater.

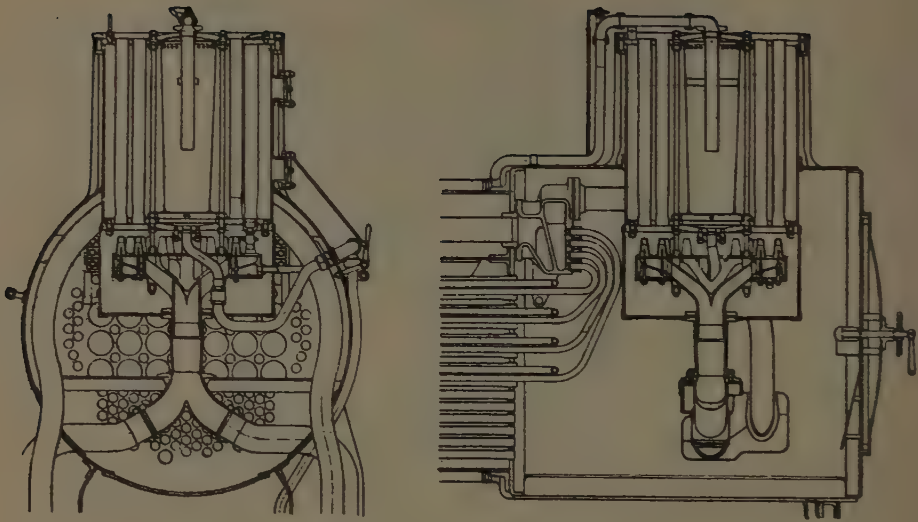


Fig. 35. — Borsig mixed gas preheater.

2.5 to 3 %. It was quite clear from the tests that the upper limit of temperature was practically fixed, and would have been attained whatever the initial temperature might have been. But the apparatus was not satisfactory in view of the initial expenditure and maintenance charges involved. The blast pipe nozzles frequently became choked and the removal of scale and rust was troublesome, while the hissing sound of the exhaust was found to be disturbing.

Figure 36 shows an experimental design of a straight-forward gas preheater for connecting behind the exhaust steam preheater. The heating surface and available temperature gradient for this were small, but considering it purely as a utiliser of waste heat, no greater preheating was expected from it than about 120° (248° F.). This design made use of the front portions of the smoke tubes not occupied by the superheater tubes and by virtually reducing the size of the smoke tubes in this region, caused an increase in the velocity of the gases. The equipment is simple and cheap and does not appreciably affect access to the smoke tubes and superheater elements. It did not, however, show any definite advantages in service because the pipes within the smoke tubes, forming the effective heating surface, were too short. Nevertheless, this preheater should be capable of development as it is possible to place the return lengths of superheater pipe still further back, or alternatively, to obtain the additional space for preheating surface by lengthening the boiler.

The flue gas preheater shewn in figure 37, and used in the Krupp turbine locomotive, showed an appreciable advantage. The boiler is relatively short and the flue gases are initially at really high

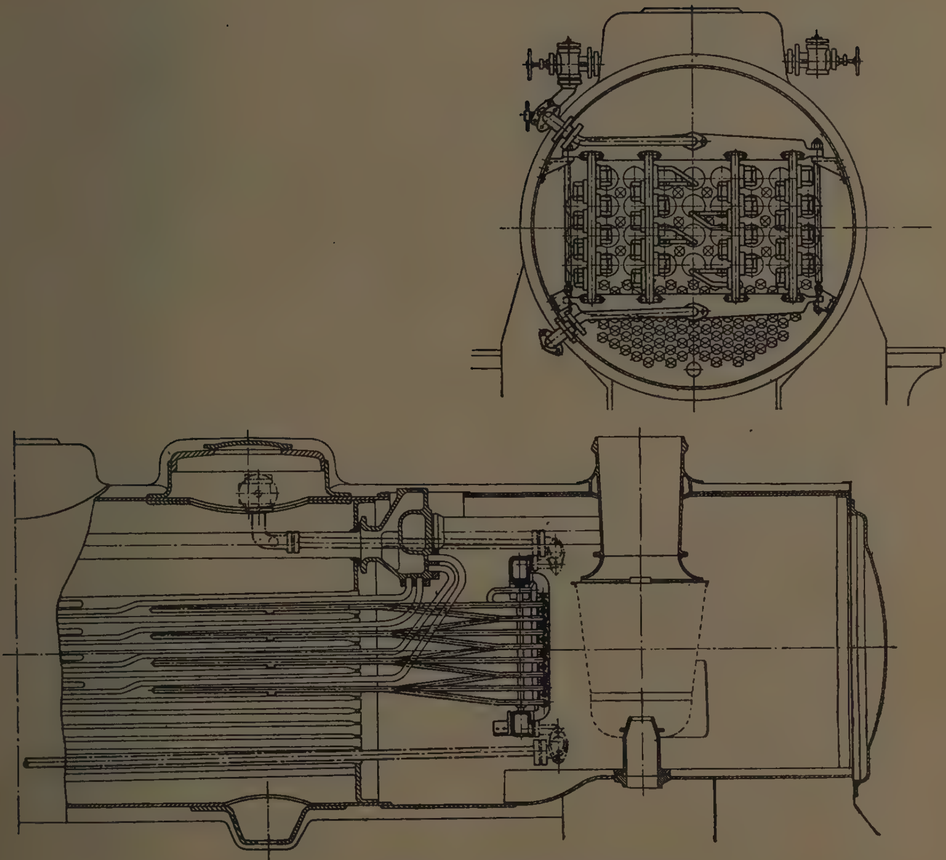


Fig. 36. — Experimental exhaust gas preheater, Head Office of the Reichsbahn.

temperatures. The preheater which is of simple form and does not impede access to the tube plate, enabled an additionl 5 % of the heat units in the coal to be recovered from the flue gases. It is now proposed to conduct further experiments with a straight flue-gas preheater on the Maffei turbine locomotive.

The experiments so far carried out have not created sufficient inducement for the general adoption of flue-gas preheaters on locomotives of the usual type; but they can certainly be used successfully to improve the boiler efficiency in individual cases, if they are adapted to suit the special circumstances.

The savings of 16 to 20 % in heat used for evaporation, that could be confidently

expected, promised a measure of success for the systematic application of exhaust steam preheating which was not attainable by the arrangements already described. Exhaust steam preheaters of serviceable designs were first at the disposal of the Reichsbahn after their main development in 1910-1914. The designs which had then been produced, typified by the Knorr pump of so-called regulation pattern and the cylindrical preheater with interchangeable U tubes, were incorporated in all new and many old suburban locomotives up to 1920. In all cases they gave considerable thermal economies, sometimes greater than was expected. This was partly due to the reduced back pressure in the blast pipes, which were then too small, leading in turn to a further decrease in the heat consumption per unit of output in the cylinders. Considerable value was also attached to the practical advantage that the pumps required only 2 to 3 % of the volume of water they dealt with, instead of the 11 to 16 % of the boiler steam, as taken by injectors. The total evaporation of the boiler was correspondingly reduced.

But neither the pump nor the preheater in their existing designs could in the long run prove satisfactory. In the case of the pump, the reason was that the driving portion had been taken from the air pump without properly considering the diverse requirements of such different substances as air and water, particularly having regard to the acceleration of the latter in long and narrow pipes. Thus a different type of valve was needed for the steam end of the water pump in order to give proper cushioning on reversal of the piston, in place of the sudden reversing action hitherto used in the air pump.

The first contribution came from Nielebock in 1921, whose proposal embodied the introduction of the economical compound working. His work in the direction of developing serviceable pumps led finally in 1925 to the introduction of the Nielebock-Knorr pump as a standard design. They were built for the Reichsbahn in two sizes for 250 l. and 350 l. (8.82 to 12.36 cubic feet) per minute for locomotives of over 1 800 indicated horse-power. For very small locomotives for secondary and narrow gauge lines, the further size shewn in figure 38 is used, with a capacity of 150 l. (5.2 cubic feet) per minute.

The new design has considerably improved the conditions owing to its greater suitability for the special requirements of water delivery. Figure 39 shows a 250 l. (8.82 cubic feet) per minute pump for medium-size locomotives. The improvements have had a particularly marked effect in reducing the wear and tear of preheaters and boiler feed valves.

The damage caused to these valves would have been still greater but for the introduction, simultaneously with the Knorr pump, of a patented valve based on the author's experiments; this is similar to that shewn in figure 40. This valve has a cylindrical guide on the cone in substitution for the web guides used previously; this obviates whirling of the water and ensures a steady upward flow.

The construction was again improved considerably in 1924-1925 by the incorporation of a cushioning spring in conjunction with a corresponding increase of the cross-section of the passages; this reduces the lift and at the same time the spring causes the plunger to approach so near to its seat towards the end of the stroke that final closing when the water colum reverses is hardly noticeable.

Coincident with these detailed improvements the pipe sizes were modified. The suction and delivery pipes on the

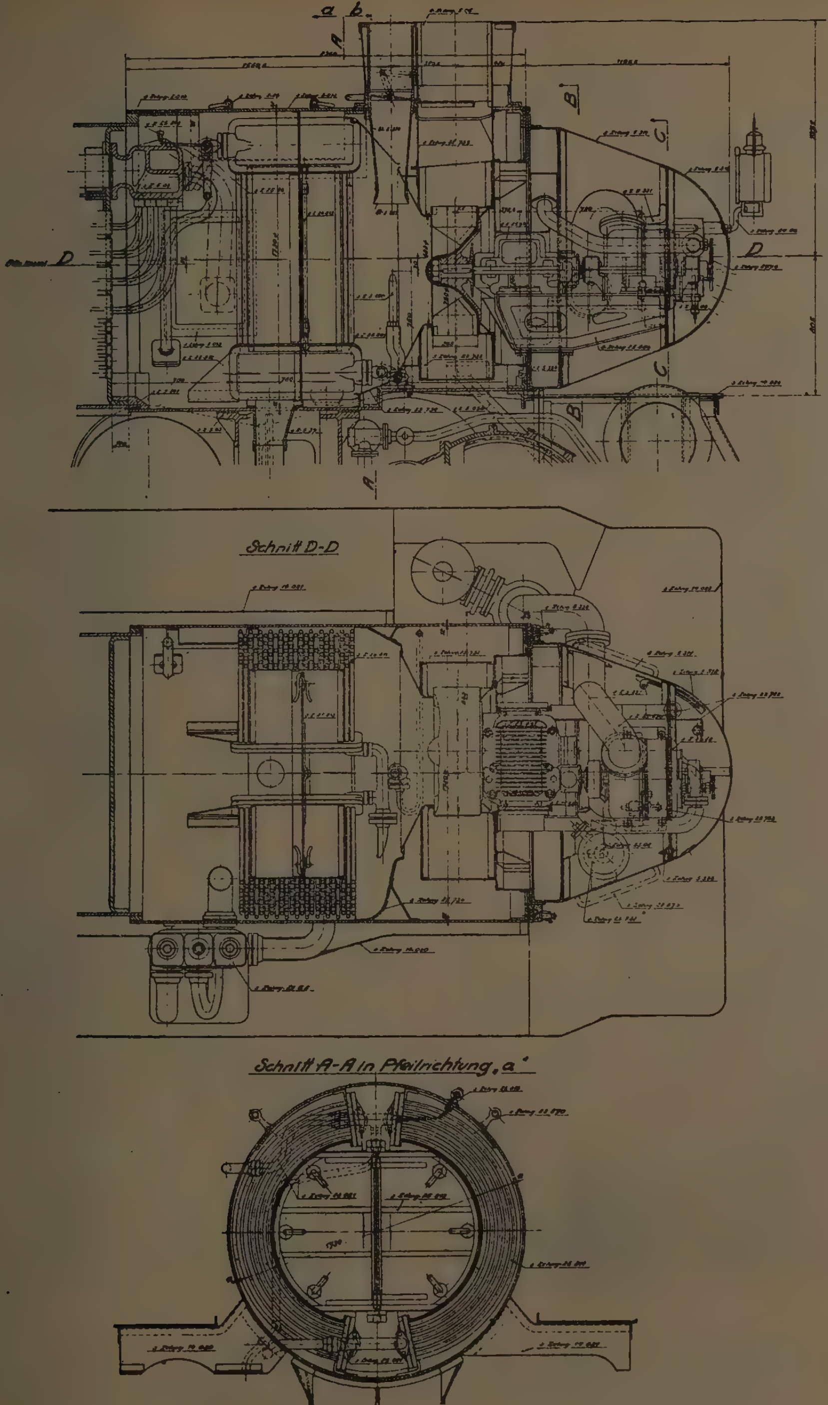


Fig. 37. — Krupp turbine locomotive : smoke box with exhaust gas feedwater heater, and turbine-driven fan.

large standard engines, for example, having 2 500 boiler horse-power, were made 70 and 80 mm. (9/32 and 5/16 inches) respectively, in order to reduce to a minimum the velocity of the water.

Scaling up of the bends of the U pipes was experienced with preheaters, and this partially blocked the pipes, especially if the boiler valve was leaky, and hot water and steam came back into the preheater. The same thing gradually occurred also in normal operation. Every possible method of cleaning has been investigated. Finally successful results were obtained by periodically immersing the nest of tubes in very weak hydrochloric acid (1 %) for 24 hours and then flushing them with a jet of water Eventually these disadvantages led to the type being abandoned in favour of straight tubes, with one tube plate and header free enough to enable the nest of tubes to expand. The water inlets were so arranged that the coldest and hottest water were as far as possible from one another, thereby avoiding temperature stresses in the headers and tubes.

This form of surface preheater is the regulation pattern now used. It has heating surface of 13 m² (140 sq. feet) and is sufficient for locomotives with 2 500 boiler horse-power and over. As furring still took place occasionally in the hotter parts, it was possible to distribute it uniformly and thereby prolong the period of service by fitting a reversing cock on the front so that the direction of flow of the water could be reversed.

A further improvement of the equipment was the provision since 1926 on the large standard locomotives of means for recovering the preheater condensate. Formerly there was reluctance to do this on account of the small amount of oil in the condensate, but this disadvantage has been met by inserting an oil separator in the return pipe, on the American model. At first a cloth filter was used, but since the filter cloths caused frequent delays, a charcoal filter was subsequently adopted with satisfactory results. Figure 43 shows such a filter; the filter medium has to be renewed or cleaned every fifty days. The water-carrying capacity has been virtually increased by 15 % and at the same time a part of the heat in the condensate is recovered. The position of the preheater is such that the condensate can drain back to the header by gravity; as shewn in figure 24, it is placed in the crown of the smoke-box in front of the chimney and immediately above the side recesses containing the pumps.

Another boiler improvement of some importance to the Reichsbahn from the operating point of view was the combination of the preheater equipment with the sludge separator shewn in figure 44. The feed water from pumps and injectors is now delivered tangentially into a whirl chamber in the top of the special dome. It issues from the outlet in the base as a conical spray which is driven against an angle-iron grid, and trickling down this is raised to a temperature at which the particles of incipient boiler scale separate out. The grid consists simply of angle-iron facing upwards like gutters so that a large surface is exposed for heating the water. The resulting sludge consisting mainly of the fur-forming particles is guided clear of the boiler tube into a sump by means of sheet-metal ducts. This arrangement, or similar ones which preceeded it, has been fitted to 5 500 locomotives and contributes appreciably to the preservation of the boiler. In designing the injector it is necessary to take in account the gradual heating up of the water in the tender, which due to the heat re-

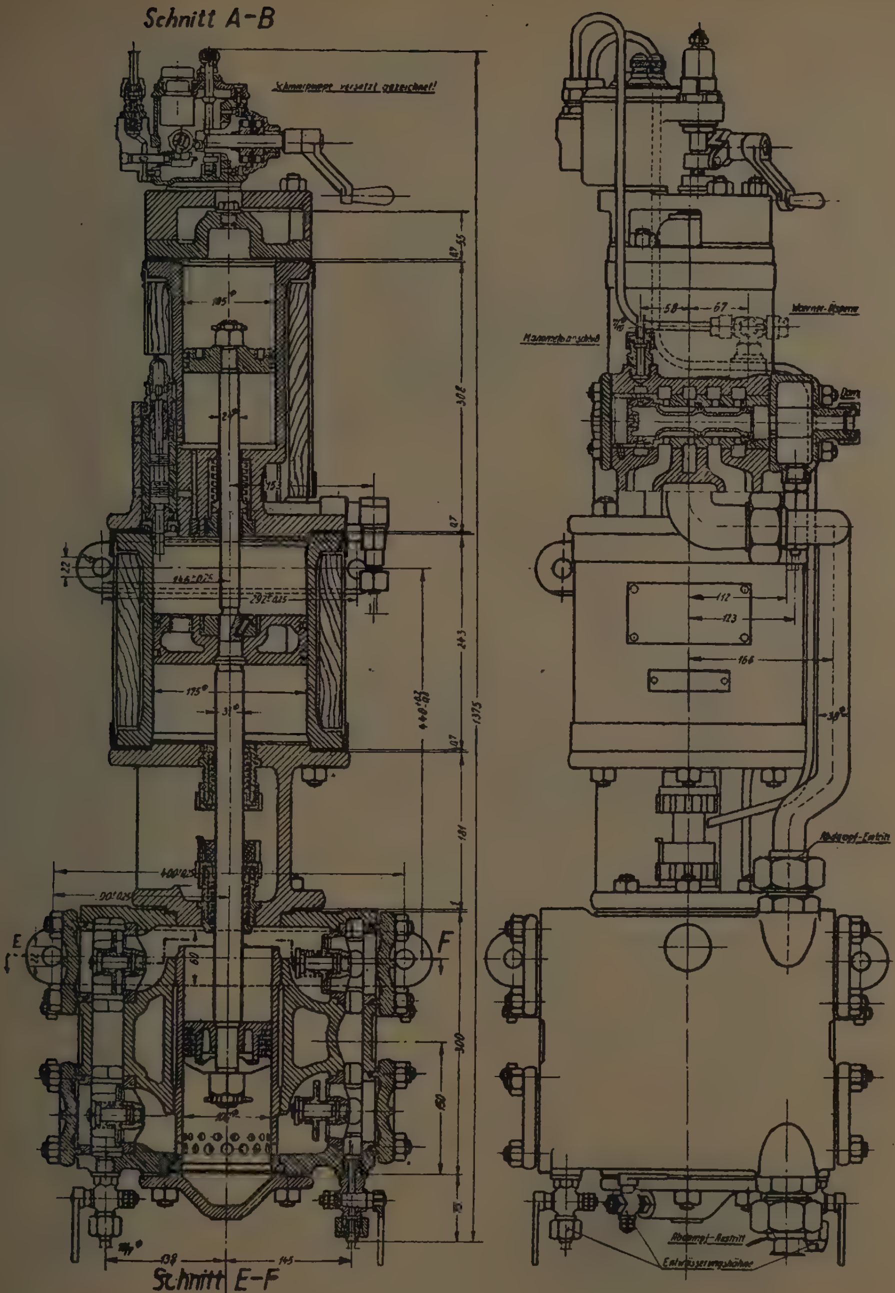
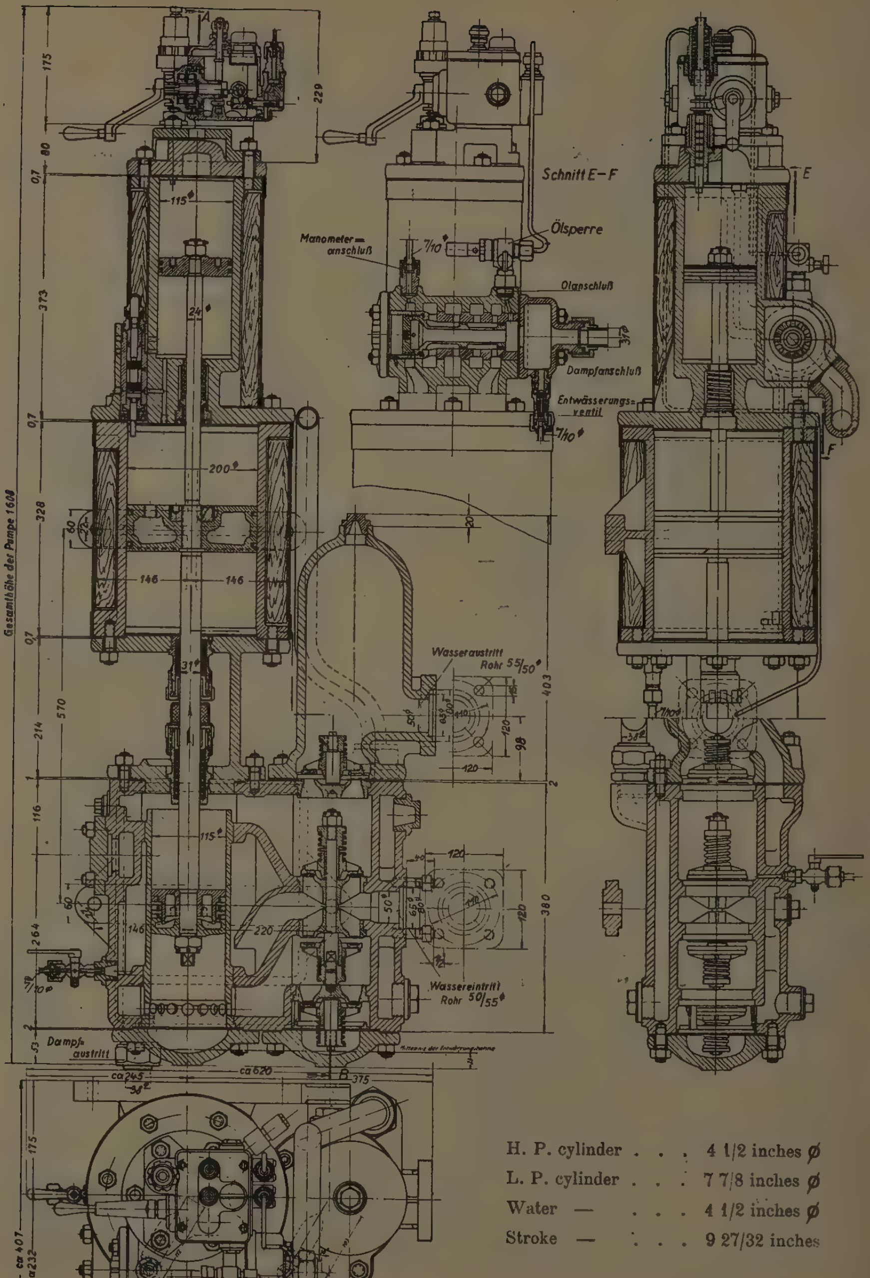


Fig. 38. — Nielebock-Knorr compound feed pump for 150 litres (5.3 cubic feet) per minute.

Explanation of German terms: Abdampfaustritt = Exit of exhaust steam. — Abdampfeintritt = Entry of exhaust steam. — Dampfeintritt = Entry of steam. — Entwässerungshahn = Discharge cock. — Manometer Anschluss = Manometer pipe. — Schmierpumpe versetzt gezeichnet = Oil pump shown turned over Wœrner Oelsperre = Wœrner oil check valve.



H. P. cylinder . . .	4 1/2 inches ø
L. P. cylinder . . .	7 7/8 inches ø
Water — . . .	4 1/2 inches ø
Stroke — . . .	9 27/32 inches

Fig. 39. — Nielebock-Knorr feed pump, 250 l. (8.83 cubic feet) per minute.

Explanation of German terms: Dampfanschluss = Steam pipe. — Entwässerungsventil — Water discharge cock. — Oelanschluss = Oil pipe. — Rohr = Tube. — Wasser-Austritt = Exit of water. — Wassereintritt = Entry of water.

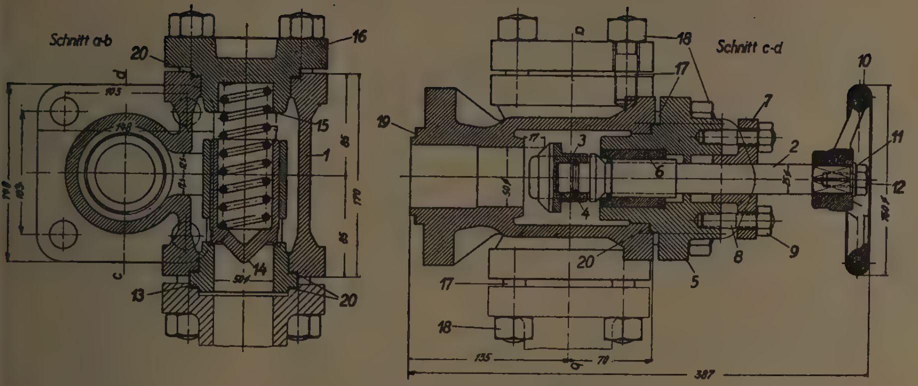


Fig. 40. — Boiler feed valve.

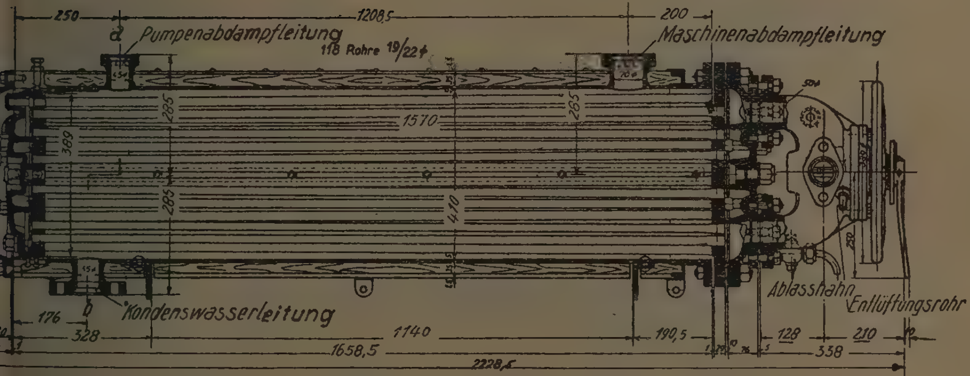


Fig. 41. — Knorr exhaust steam preheater with straight tubes.

Explanation of German terms: Pumpen (Maschinen) Abdampfleitung = Exhaust steam pipe of the pump (of the engine). — Rohre = Tubes. — Kondenswasserleitung = Condensate pipe. — Ablasshahn = Drain cock. — Entlüftungsrohr = Air exhaust pipe.

turned by the condensate may rise to 35° C. (95° F.). Messrs. Schäffer & Budenberg have produced a suction injector with a second spill chamber which is capable of drawing water at temperatures up to about 50° C. (122° F.) and has a capacity of 300 to 350 l. (10.60 to 12.36 cubic feet) per minute.

A discussion of the improvement of normal locomotives by increasing their thermal efficiency, by the use of more satisfactory components, and by other

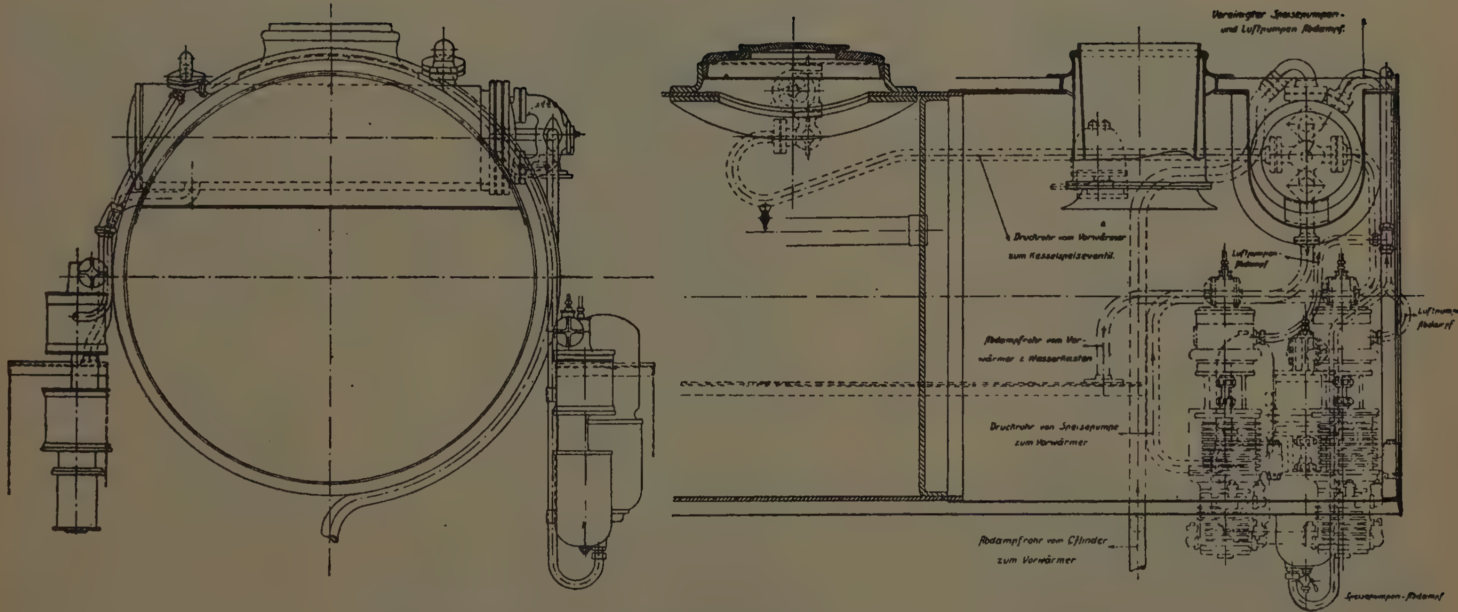


Fig. 42. — Arrangement of preheater on top of the smoke box.

Explanation of German terms: Vereinigter Speisepumpen- und Luftpumpen-Abdampf = Mixed exhaust steam from feed pump and air pump. — Druckrohr vom Vorwärmer zum Kesselspeiseventil = Pipe through which water is driven from preheater to boiler feed valve. — Abdampfrohr vom Vorwärmer z. Wasserkasten = Exhaust steam pipe leading from preheater to water tank. — Druckrohr vom Speisepumpe zum Vorwärmer = Pipe through which water is driven from feed pump to preheater. — Abdampfrohr vom Zylinder zum Vorwärmer = Exhaust steam pipe leading from cylinder to preheater. — Luftpumpenabdampf = Exhaust of air pump. — Speisepumpenabdampf = Exhaust of feed pump.

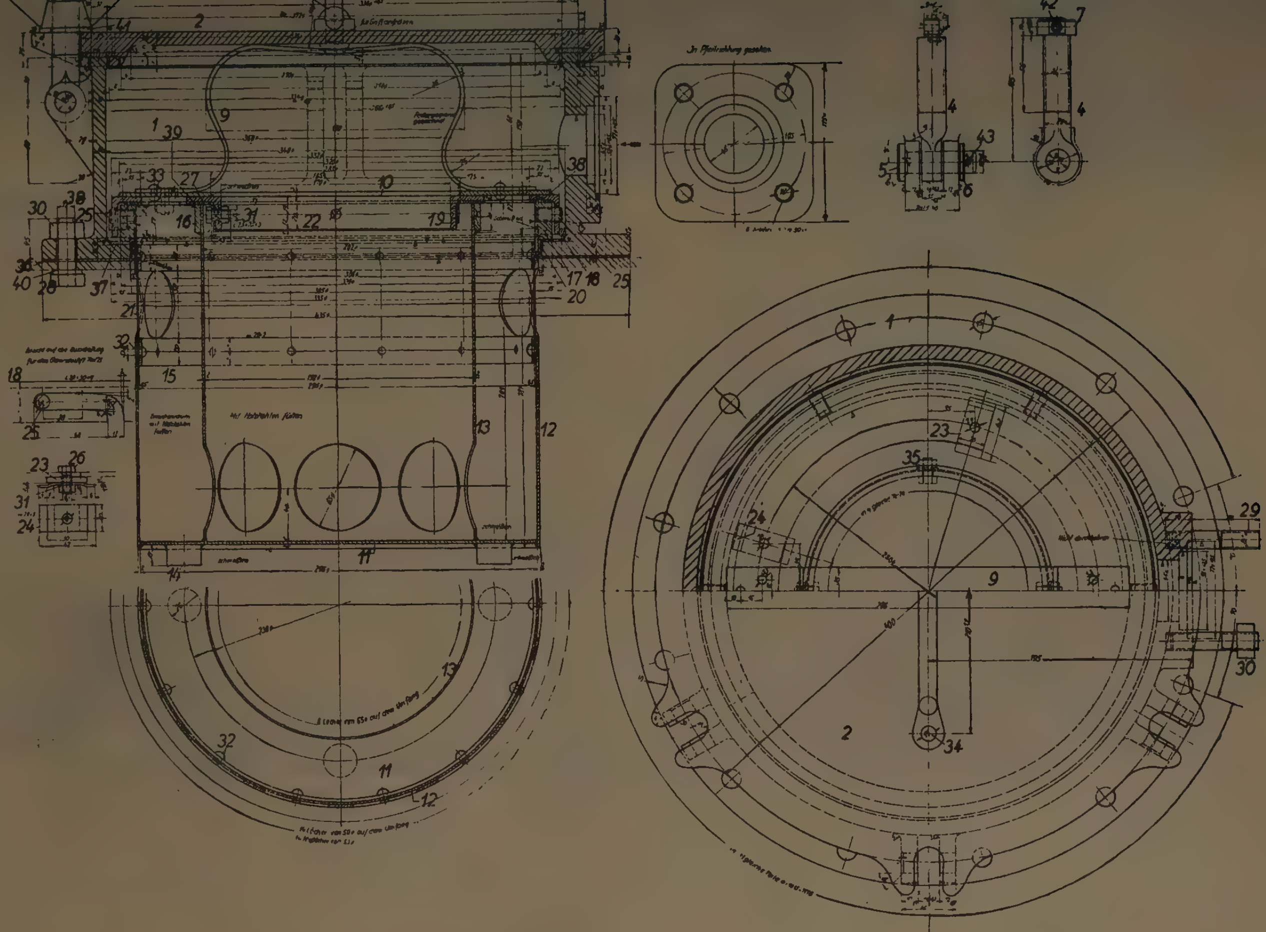


Fig. 43. — Oil separator.

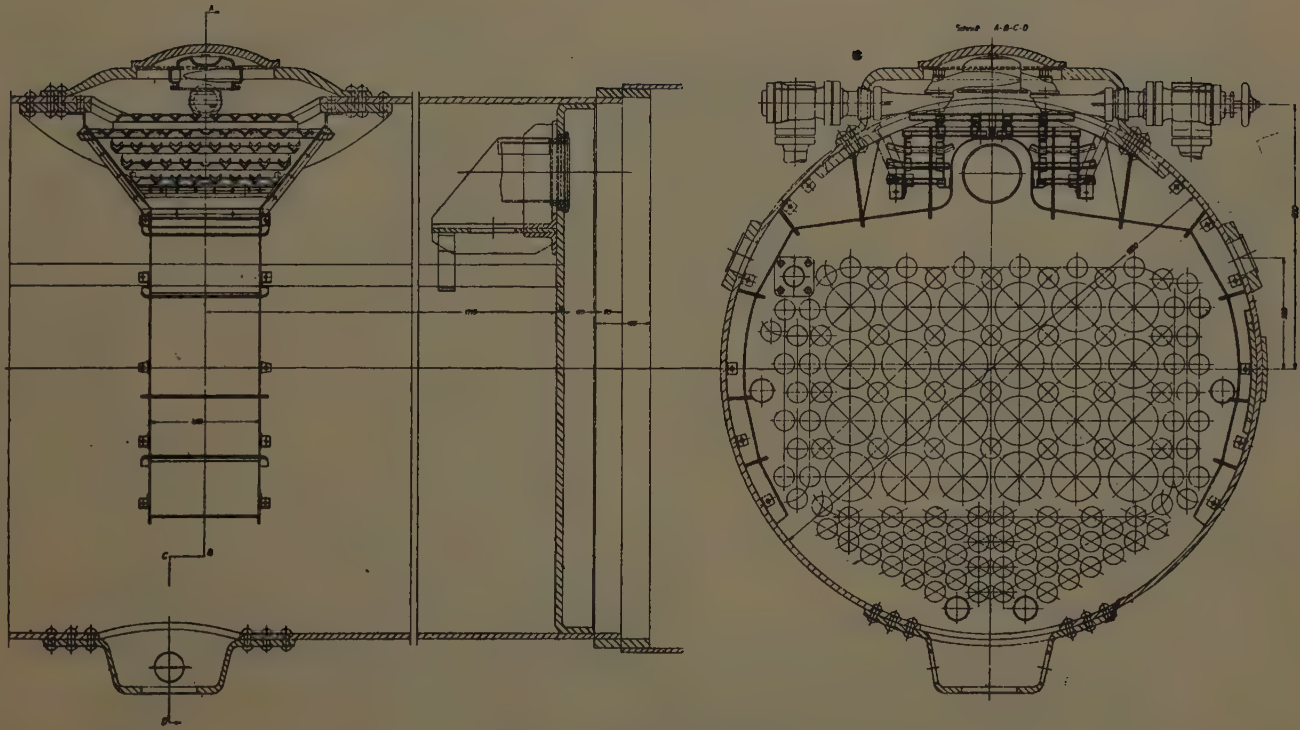


Fig. 44. — Sludge separating device.

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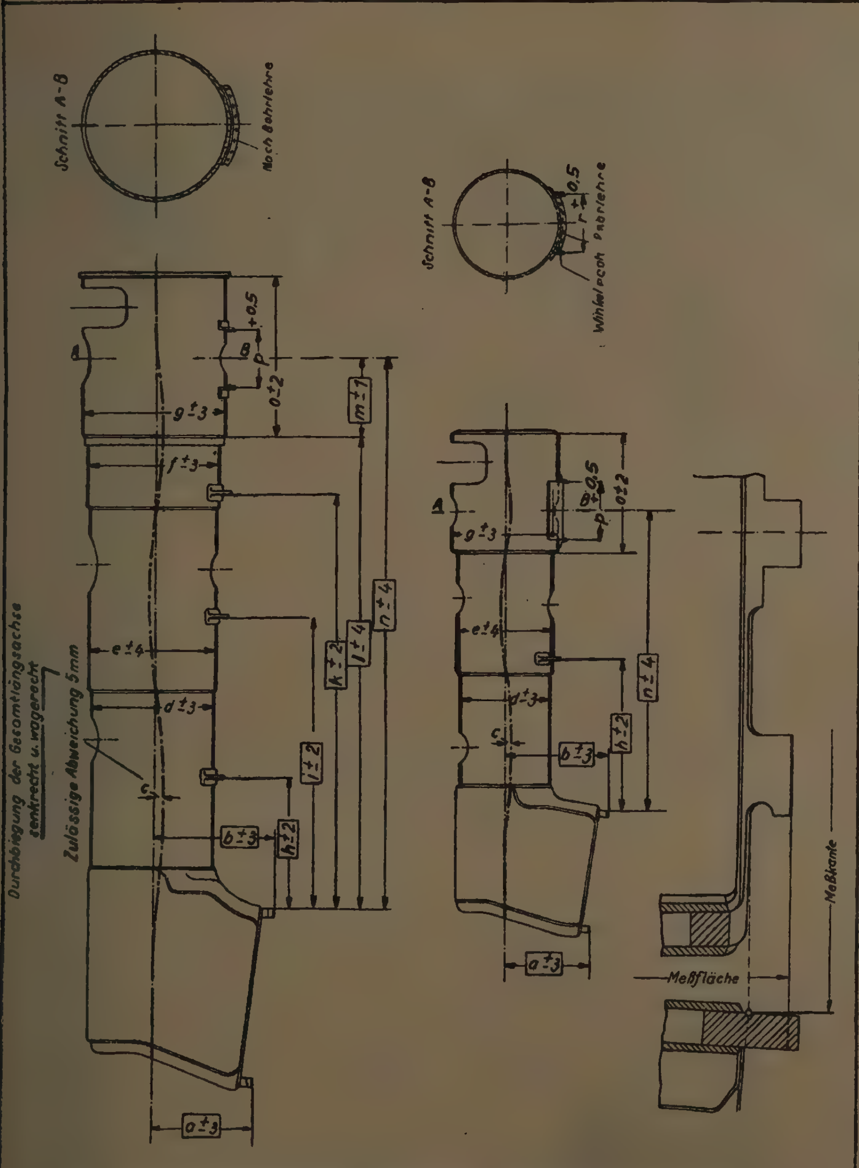

Für die Abnahme zusammengebauter Teile sind die Einbautoleranzen maßgebend ▭

Fig. 45. — Tolerance instruction sheet for standard locomotives of the Deutsche Reichsbahn. — Boiler.

Explanation of German terms: Durchbiegung der Gesamtlängsachse senkrecht und wagerecht = Vertical and horizontal flexion of the whole of the longitudinal axis. — Zulässige Abweichung = Permissible difference. — Winkel = Angle. — Nach Bohrlehre = According to drilling templet. — Messkante = Check edge. — Für die Abnahme zusammengebauter Teile sind die Einbautoleranzen massgebend = For the inspection of assembled parts, the erection tolerances will be observed.

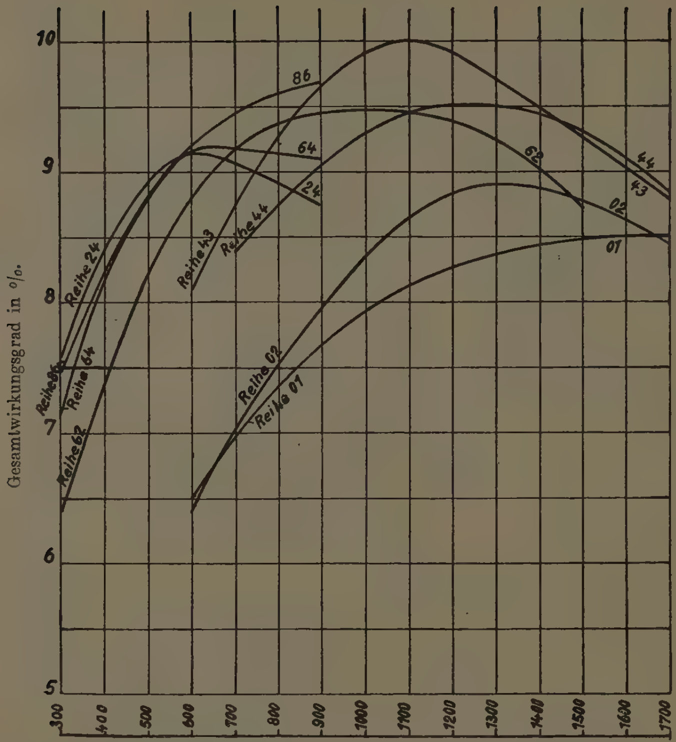

Fig. 46. — Efficiency of standard locomotives.

Explanation of German terms: Gesamtwirkungsgrad in % = Total efficiency in %. — Zughakenleistung in PSe = Power developped at the drawbar hook in effective H. P. — Reihe = Series.

means, would not be complete without reference to the influence of more highly developed methods of manufacture and maintenance. Much detail work has been devoted to this subject during the last few years. Consider for example only the production of new locomotives. By specifying tolerances which cover all the principal dimensions of a part and by expert supervision, manufacture is now on such a basis that interchangeability can be guaranteed.

Tolerances are issued as complete instructions of the form indicated in the example of figure 45. The observance of these instructions, and inspection extending to each individual toleranced dimension, are at the present time matters within the purview of the locomotive works administration as part of the fulfilment of their task. The introduction of these methods has contributed to making the standard engines built under it, and in which are incorporated the other

improvements covering the individual components, the most economical and serviceable machines in the depots of the Reichsbahn. Some indication of this may be found in the curve sheets of figures 46 and 19, which include the overall efficiencies referred to the tender draw-bar pull; they show a maximum of 9 % for the express locomotives and 10% for the 1 E freight locomotives. The curve of the latter is bound to be higher, since by virtue of their lower speed they take less power themselves than the xpress locomotives.

[621 132. 8 & 656. 22]

REPORT N° 3

(Belgium, France, Italy, Portugal, Spain and their Colonies)

ON THE QUESTION OF ECONOMICAL TRACTION METHODS FOR USE IN PARTICULAR CASES (SUBJECT XII FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION) (1) (2),

By O. A. GAEREMYNCK,

Principal Engineer in the Traffic Department of the Belgian National Railway Company.

Fig. 1 to 19, pp. 149 to 182.

QUESTION XII.

Economical traction methods for use in particular cases as for example :

A. — Organisation of train services on the minor lines of the large systems carrying little traffic and of little used trains of the more important lines of these systems.

B. — Use of special tractors for shunting in smaller yards and for certain work in large yards.

The questionnaire for Question XII was sent to the Belgian, French, Italian, Portuguese and Spanish Administrations members of the International Railway Congress Association, and replies have been received from 40.

QUESTION XII — A.

Of the replies received, only those from the 12 undermentioned Companies give any information :

1.— North of Spain Railways.
2.— French State Railways.
3.— French Est Railway.
4.— French Nord Railway.
5.— Paris-Lyons-Mediterranean Railway.
6.— Paris-Orleans Railway.
7.— Tarn Departmental Railways.
8.— French West African Railways.
9.— Italian State Railways.
10.— Reggio-Emilio Railway.
11.— Vercellesi Tramways.
12.— Belgian National Railway Company.

(1) This question runs as follows : « *Economical traction methods for use in particular cases, as for example :*

A) Organisation of train services on the minor lines of the large systems carrying little traffic and of little used trains on the more important lines of these systems.

B) Use of special tractors for shunting in smaller yards and for certain work in large yards ».

(2) Translated from the French.

The railways numbered 1, 3, 8, 10, 11 and 12 use no form of power other than more or less low powered locomotives for lines carrying little traffic or for light trains on their main lines.

The other Administrations have, on the other hand, some steam or internal combustion engined rail cars. Of these Companies some are carrying out tests with Diesel locomotives or with Diesel-electric rail cars.

These vehicles are as shown in the following table :

RAILWAY.	Steam rail cars.	Internal combustion engined rail cars.	Diesel locomotives.	Diesel-electric rail cars.	Diesel rail cars with mechanical drive.
French State	...	11 in service.	...	...	...
French Nord	10 in service.	...	...	...	...
Paris - Lyons - Mediterranean.	4 in service.	2 in service on the Algerian narrow gauge line. (3 ft. 5 3/8 in.) 2 on order for use in France.	...	Proposed for Algerian lines.	...
Paris-Orleans.	...	1 in service (metre gauge).	...	...	...
Tarn	...	3 in service (metre gauge).	...	..	...
Italian State	...	1 in service.	Trial proposed.	Trial proposed.	...
Belgian National Railway Company.	...	...	...	Trial proposed.	Under trial.

Steam locomotives.

The *French State Railways* use six-coupled steam locomotives of 40 t. (39.4 Engl. tons) weight, 30 of which have been arranged to be operated by one man, while a similar number are still to be altered; they are of an old type dating from 1884.

The *Paris-Orleans Railway* put into service, in 1928, two locomotive brake vans (fig. 1); these consisted of old saturated 2-4-2 standard-gauge express locomotives which have been provided with side tanks, the tender being converted into a brake van in addition to carrying the coal. A door is provided to give access from the brake van to the footplate, and in view of this direct communication between the guard and the driver, the operation of the engine could be and is satisfactorily carried out by one man on the footplate.

Coal (mixed) is used as fuel.

The engine, without tender, weighs 45 t. (44.4 Engl. tons) in working order, the theoretical tractive effort at 100 % cut off = 6 292 kgr. (13 870 lb.), 65 %

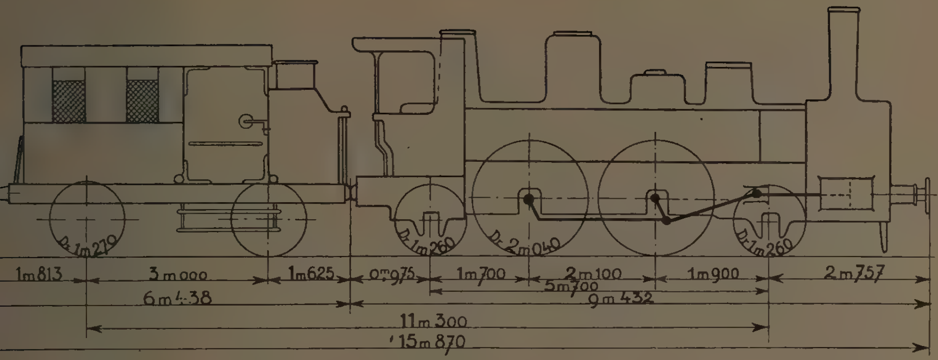

Fig. 1. — Paris-Orleans tank locomotive with van.

of the theoretical tractive effort = 4 090 kgr. (9 015 lb.).

The total wheel base of engine and tender brake van is 15.870 m. (52 ft. 1 in.).

The Italian State Railways have 317 small simple expansion tank engines of the 0-6-0 or 2-6-0 type, with two outside cylinders, weighing 40 to 50 t. (39.4 to 49.2 Engl. tons) respectively in working order, the most recent of the 2-6-0 engines being fitted with Schmidt superheaters.

The Belgian National Railway Company has about 40 small simple expansion saturated tender engines purchased between 1888 and 1898. The other administrations do not give any information concerning small engines they have in service.

Rail cars.

Steam.

Of the ten steam rail cars in service on the *French Nord Railway*, two date from 1901, and the other eight from 1908 to 1909, and they are entirely satisfactory.

The *Paris, Lyons & Mediterranean Railway* on the other hand has abandoned the use of steam rail cars; they only have four in service, the last of a group of twelve purchased in 1907, and these will shortly be withdrawn on account of the high maintenance cost. It is mentioned in particular that the water tubes of the Purrey type frequently fail in service, the tubes burst and rapidly scale up.

The steam cars on the French Nord Railway (fig. 2) consist of a small engine and brake van on four wheels, one pair of which drive, close coupled between two coaches. When repairs are necessary, the engine unit can thus be replaced.

The boiler is of the locomotive type with Serve tubes and has no superheater.

The engines have two cylinders, simple expansion in the case of eight of the rail cars and compound for the two others. Dimensions : 250 mm. (9 7/8 inches) diameter by 320 mm. (12 9/16 inches) stroke for the simple engines, and 195 and 250 mm. (7 3/4 and 9 7/8 inches) diameter respectively by 320 mm. (12 9/16 inches) stroke for the compounds. Walschaerts gear with flat slide valves is used.

The heating surface is 30 m² (323 sq. feet) for the compound rail car (66 Serve tubes 50 mm. [2 inches]) external diameter, 1.545m. (5 ft. 13/16) in length and 53.5 m² (576 sq. feet) for the simple engines (92 Serve tubes 2.038 m. (6 ft. 8 1/4 in.) long. The working pressure is 16 and 14 kgr. per cm² (227.6 and 199.1 lb. per sq. inch) respectively, and the weights in working order are 21.8 and 26.4 t. (21.4 and 26 Engl. tons). 2 450 litres (539 Brit. gallons) of water are carried and 1 150 kgr. (2 535 lb.) of fuel, which is a mixture of coal and briquettes in equal parts.

The two special coaches weigh 10 t. (9.8 Engl. tons) each and accommodate 58 passengers seated and 26 standing, in three classes. The total tare weight is therefore 47 t. (46.3 Engl. tons)) that is, 560 kgr. (1 235 lb.) per passenger carried. Additional accommodation may be obtained by an ordinary 12-t. (11.8 Engl. tons) coach for 60 passengers on lines on which the gradients do not exceed 1 in 200.

The vehicles are steam heated and lighted by oil lamps.

The rail cars are operated by one man on the footplate, the guard having direct access from his compartment to the engine cab, which is carried on the centre unit and is raised so as to provide a look out in both directions.

The maximum speed on the level is about 60 km. (37.3 miles) per hour; a line 17 km. (10.6 miles) long, of which 5 km. (3.1 miles) is on an incline of 1 in 66 is accomplished in 30 to 37 minutes with five intermediate stops at an average speed of 40 to 45 km. (24.9 to 28 miles) per hour. The maximum distance which can be run in normal service as governed by the supply of fuel and water carried, necessity for cleaning fire, etc., is about 100 km. (62 miles).

No special difficulty is met with as regards maintenance, although, with some waters, injectors have to be frequently inspected, owing to the small diameter of the cones.

The most up-to-date steam rail car (figs. 3, 4, 5, 6 and 6*bis*) is that mentioned by the Paris-Orleans Railway, and which was built in 1925. It is fitted with a Sentinel boiler with an internal firebox and straight water tubes, inclined to obtain good circulation, of solid drawn steel arranged as shown in figure 4. The boiler shell is 1.34 m. (4 ft. 4 9/16 in.) high and has an outside diameter of 0.826 m. (2 ft. 8 1/2 in.); the joints are made with graphited asbestos rings and the boiler is lagged externally. The working pressure is 19.3 kgr. (275 lb. per sq. inch) and the steam is superheated to about 260° C. (500° F.) [about 55° C. (100° F.) of superheat].

The fuel (small semi-bituminous coal) is fed semi-automatically. The coal is contained in a hopper from which it may be passed into the firebox by operating by hand an endless screw; this arrangement allows the engine to be operated by one man.

Feed water is introduced by a mechanical pump and by an injector. The water from the pump is heated before entering the boiler by a feed water heater which recovers part of the heat lost in the exhaust steam.

The engine has two cylinders, 171 mm. (6 3/4 inches) diameter by 229 mm. (9 inches) stroke; distribution is by poppet valves operated by a cam shaft. The pistons drive a crank shaft which drives the two axles of the driving bogie by chains through a jack shaft.

The power may be controlled by vary-

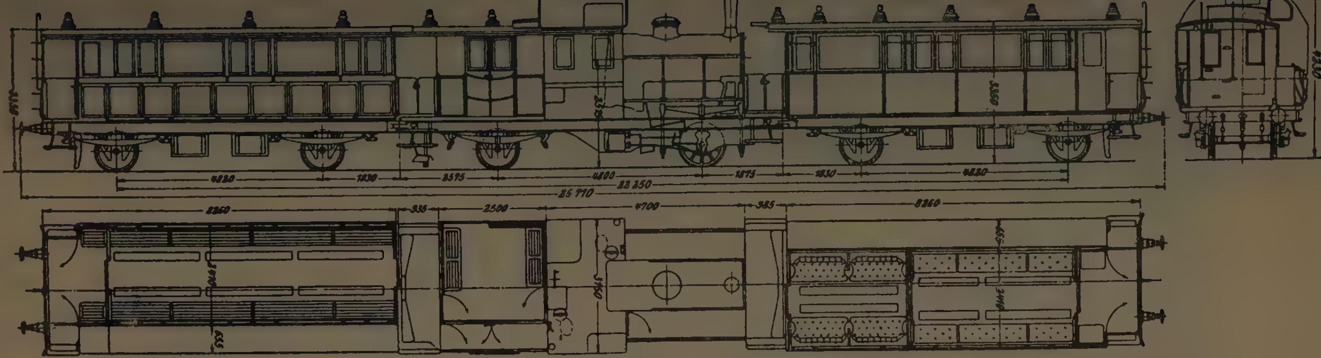

Fig. 2. — French Nord steam rail motor unit.

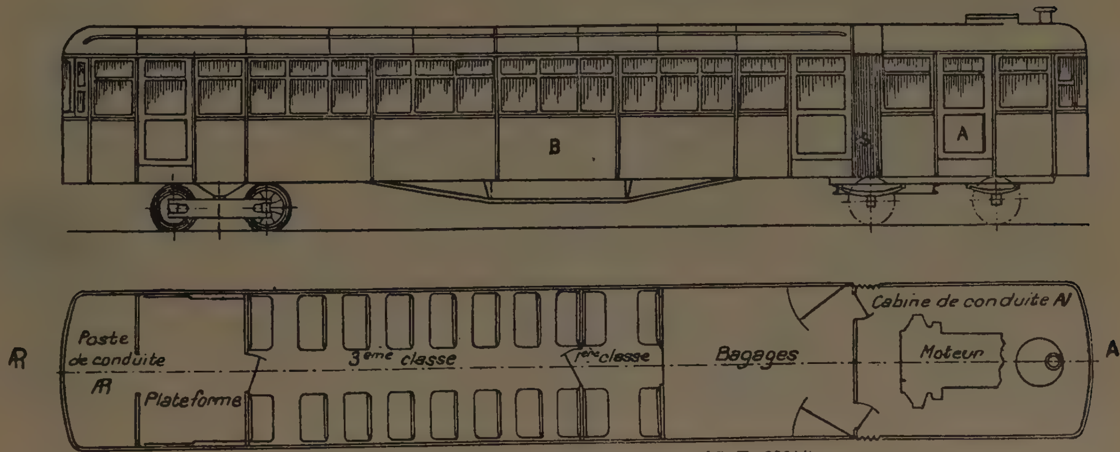

Fig. 3. — Sentinel steam rail motor coach (zzz A^1C^4 Ey 23911).

Explanation of French terms : Bagages = Luggage. — Cabine de conduite Av. = Forward driver's compartment. — Moteur = Motor. — Plateforme = Platform. — Poste de conduite Ar. = Rear driver's compartment.

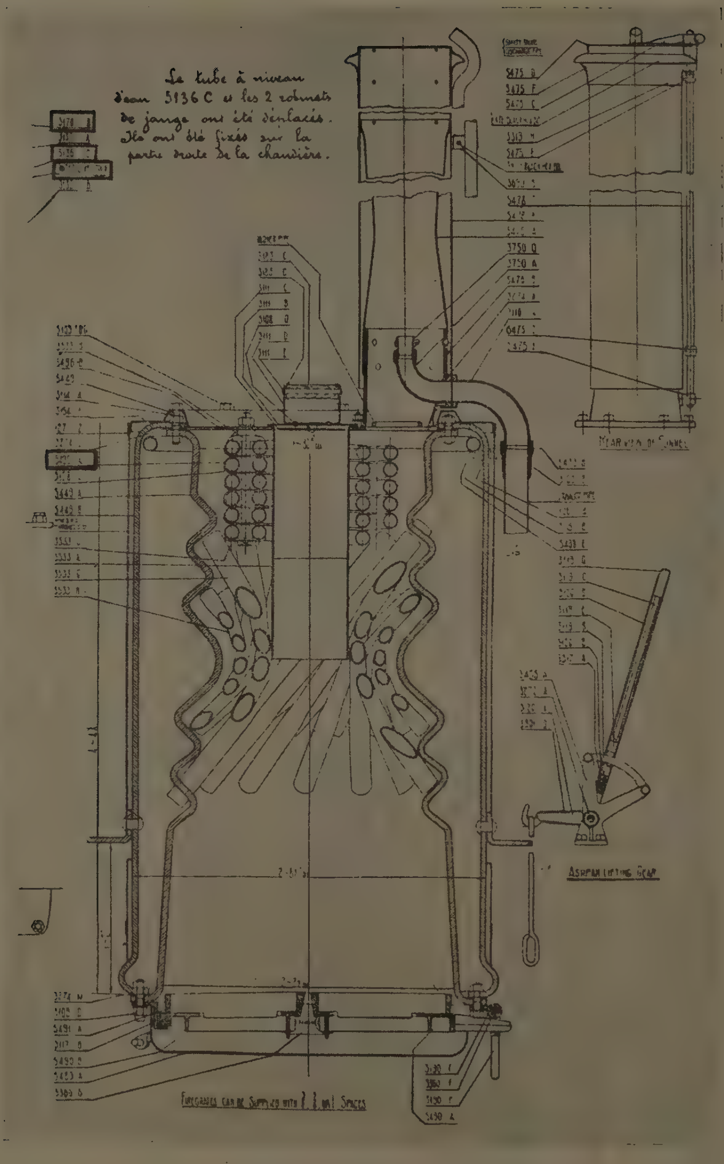

Fig. 4. — Sentinel steam rail motor boiler.

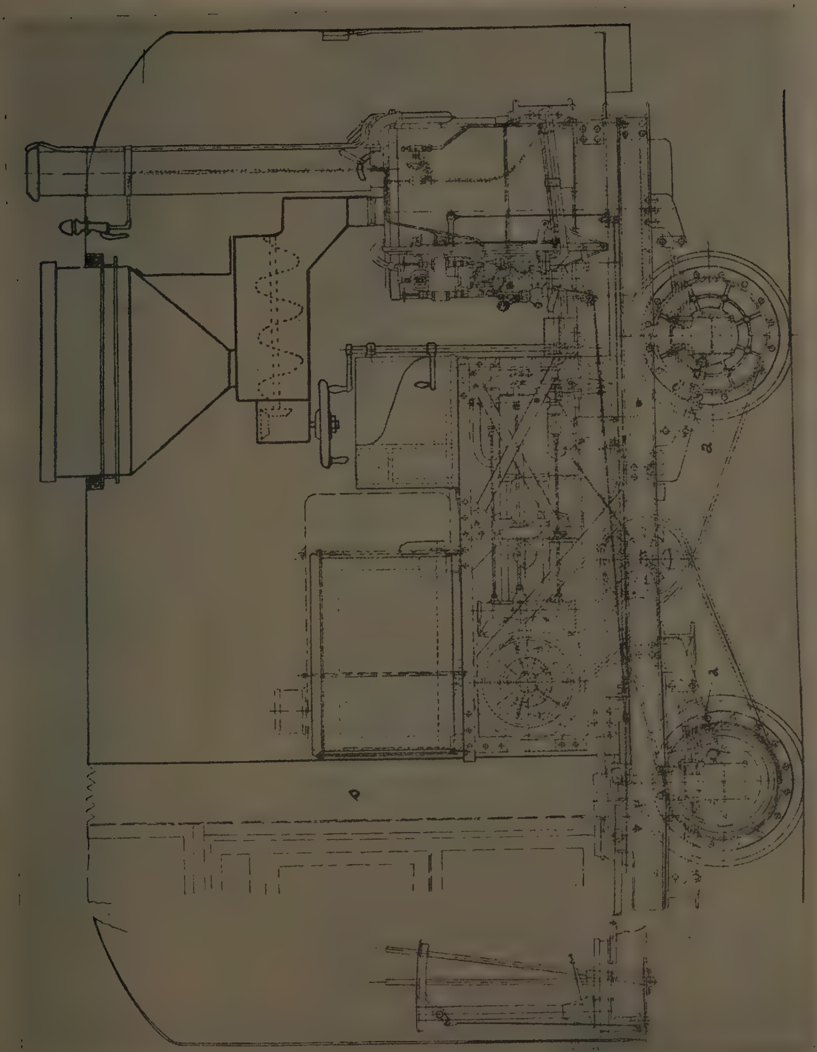

Fig. 5. — Sentinel steam railway motor coach.

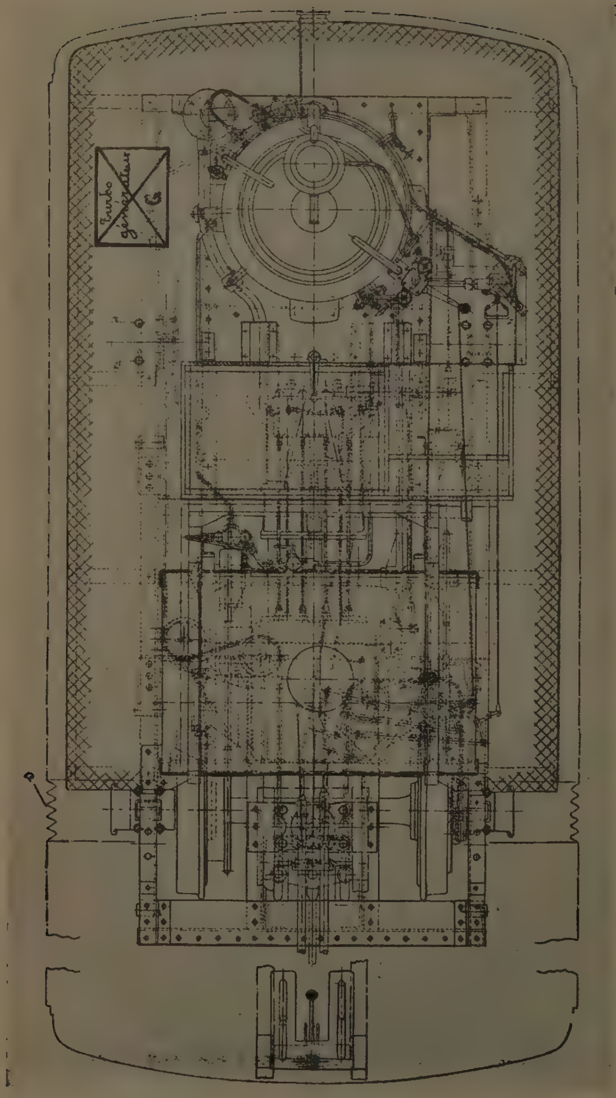

Fig. 6. — Sentinel steam rail motor coach.

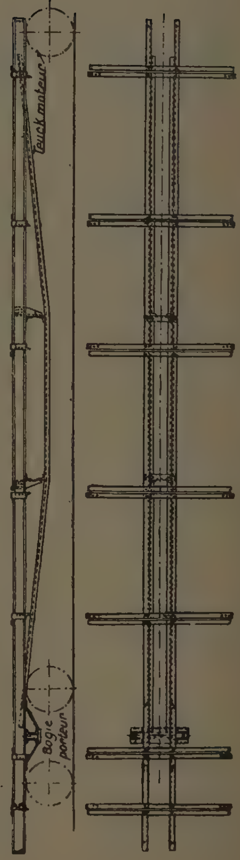

Fig. 6bis. — Body frame. Sentinel steam rail motor coach.

ing the cut off, there being two positions for both directions of running, giving cut offs of 30 and 80 % respectively.

The working parts are lubricated by splash lubrication, the cylinders being lubricated by admitting atomised oil from a mechanical lubricator into the admission steam.

The rail cars weigh 23.5 t. (23.1 Engl. tons) empty and 32.5 t. (32 Engl. tons) loaded with 2 000 kgr. (4 400 lb.) of luggage and 56 passengers; the tare weight per passenger is therefore about 450 kgr. (990 lb.).

The engine bogie is separate from the frame of the coach, to which it is connected by a pivot; rubber buffers absorb all vibrations.

The vehicle is fitted with a non-automatic vacuum brake and a hand brake; the vacuum is produced by a steam ejector. Both hand and vacuum brakes are operated on ferodo lined brake shoes acting on brake drums carried by the driving wheels.

Braking effect may also be obtained by reversing the engine but this seriously stresses the working parts. If the combustion gases are drawn into the cylinders, the valves become overheated and carbonise, while if air is drawn into the cylinders, the lubricating oil burns as in a Diesel engine.

No sandboxes are fitted. Ordinary buffers and draw gear are fitted, but of a lighter type, being provided mainly to allow the rail car to be shunted.

Heating is by means of exhaust steam from a « Pyle » turbo-generator taking steam from the boiler, producing current for electric lighting; if necessary, the boiler supplies live steam.

The rail car is normally worked chimney first and therefore can be operated by one man, in view of the semi-automatic firing device already mentioned. For running in the reverse direction, two men are necessary, one in the driver's compartment at the leading end, and the other to control the boiler. These two compartments are one at each end. A door gives access whilst in service between the engine and the luggage compartment in which the guard rides; the latter sees that the driver observes the signals and stops the train in case the driver fails to do so.

The rail car has, up to the present, run by itself on the line from La Châtre to Guéret, 76 km. (47.2 miles). The gradients on this line do not allow a trailer to be used. It is, however, to be taken off this line, where the peak traffic on certain days may be 100 passengers, although the average traffic is only 28 passengers; it will be used on a service with lighter traffic.

The Sentinel rail car has required considerable maintenance. It is one of the first built for the standard gauge, and certain parts were insufficiently strong and had to be modified, that is, the main frame, the axles and springs and transmission. The difficulty in obtaining spare parts led to the car standing out of service for long periods. In January 1929 the Company stated that they could not yet give any definite information on the ultimate maintenance costs of this rail car.

Internal combustion rail cars.

The *French State Railways* commenced in 1922 to use internal combustion rail cars working on petrol (fig. 7). They have had two cars since 1925. The engine has four cylinders 135 mm. (5 5/16 inches) diameter and 170 mm. (6 11/16 in.) stroke, developing 85 H. P. at 1 500 revolutions per minute. Transmission is

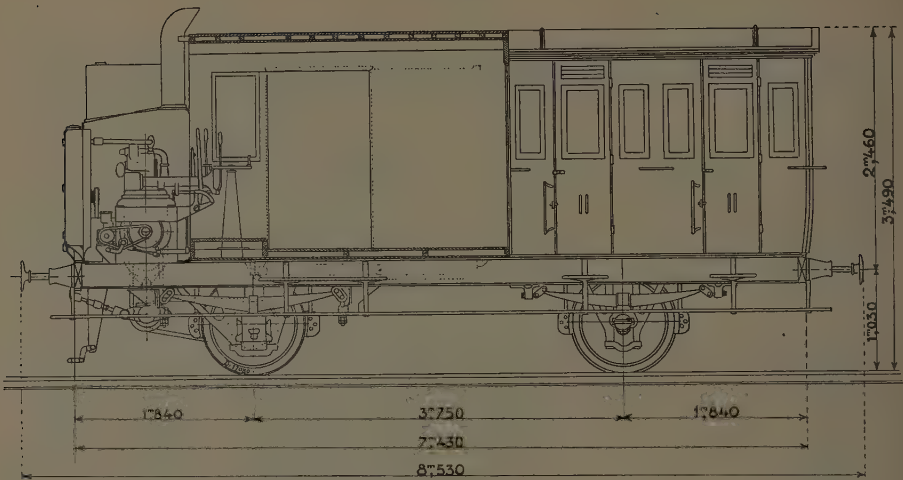

Fig. 7. — French State petrol rail motor coaches.

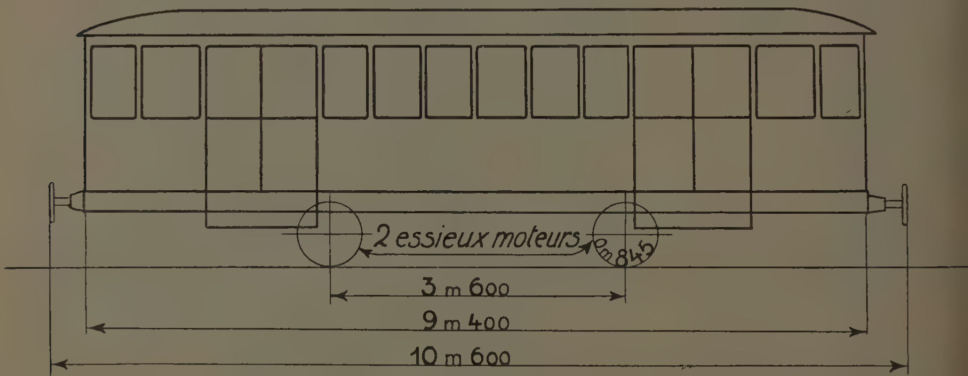

Fig. 8. — Renault petrol rail motor coach for metre gauge.
Explanation of French terms : 2 essieux moteurs = 2 driving axles.

by chains to jack shaft and from jack shaft to axle.

The rail car weighs 14.5 t. (14.3 Engl. tons) empty with 200 kgr. (440 lb.) of fuel. The total weight with passengers and luggage is 16.5 t. (16.2 Engl. tons) and the seating accommodation 20.

It is generally used with trailers attached, taking three 10-t. (9.8 Engl. tons) trailers at 50 km. (31 miles) per hour on the level, two trailers at 30 km. (18.6 miles) per hour on a gradient of 1 in 100 and one trailer at 25 km. (15.5 miles) per hour on a gradient of 1 in 50. These trailers have 70 seats, 20 second class and 50 third class.

The rail car is fitted with Westinghouse air brake and an air whistle; it is heated by the exhaust gas from the engine, foot warmers being used in the trailers.

It is used on lines having gradients of 1 in 71 and 1 in 66. The maximum length of run is 89.5 km. (55.6 miles). The average speed is 73 km. (45.4 miles). The timings give very little margin, but although it is difficult to make up lost time, time keeping is satisfactory.

Eight units are at present in use, three being out of service for inspection, repairs and as reserve.

The car is operated by one man who is located at the front close to the motor; in case of sudden illness of the driver, the guard can switch off the ignition and stop the train.

No mention is made of any maintenance difficulties; however, the State Railways consider that these cars have been in service too short a period to give any definite conclusions.

The Blanc to Argent Railway, which is a subsidiary of the Orleans Company, have used since 1925 a four wheeled Renault rail car for metre gauge track (fig. 8); the 4-cycle internal combustion engine has 4 cylinders 125 × 160 mm. (5 ×6 5/16 inches) arranged in pairs; its output is 60 H. P. at 1 200 revolutions per minute.

Electric starting is provided so that the engine can be stopped when standing for any length of time.

Transmission is mechanical, consisting of a ferodo lined cone clutch, a gear box giving 4 speeds in either direction and cardan shafts.

The fuel normally used is commercial petrol, but the motor will also work on heavy fuel distillate, benzol, or a mixture of alcohol and benzol.

Only one man is employed, he does not however issue tichets. The service is authorised by a Ministerial order under the condition that the number of passengers does not exceed the number of seats and, except under certain exceptions, no luggage, parcel or animals are carried. The rail car is fitted with telephonic apparatus whereby it is possible to connect into the line alongside the track in order to notify any case of failure. A door is provided between the driving compartments, which are one at each end, and the passenger compartment; this is provided with an emergency valve for operating the compressed air brake, which is both semi-direct and automatic.

This brake operates on brake drums on the 4 wheels by means of segments lined with ferodo. There is also a hand brake operating on the 4 brake drums and a foot brake operating on the transmission.

The air for the brake is provided by a compressor direct driven from the engine; the governor puts this in action to maintain the pressure in the main reservoir. The compressor also provides air for the whistle. Hand sanders are fitted to the four wheels for either direction of running.

Heating is by means of exhaust gas from the engine.

Electric lighting is provided, current being produced by the starting dynamo.

The maximum normal speed is 50 km. (31 miles), this being the limit imposed by the regulations, 40 km. (25 miles) may be obtained on a gradient of 1 in 66. The average speed, deducting stopping time, is 38 km. (23.6 miles).

The rail car which is used on a run of 72 km. (44.7 miles), including a maximum gradient of 1 in 66 for 2 458 m.

(1.53 mile), weighs 13 t. (12.8 Engl. tons) empty and 16 t. (15.7 Engl. tons) with 40 passengers. The tare weight is therefore only 325 kgr. (495 lb.) per passenger. A trailer, weighing 4.5 t. (4.4 Engl. tons) and carrying 14 passengers seated and 16 standing, may be attached. In this case the speed up the gradient of 1 in 66 is reduced to 35 km. (21.7 miles) per hour.

150 litres of fuel are carried, this being sufficient for a distance of 400 to 500 km. (250 to 310 miles) at a rate of 32 litres per 100 km. (11.3 British gallons per 100 miles). Actually the daily distance is 140 km. (87 miles) on week days and 200 km. (124 miles) on Sundays.

No maintenance difficulties have arisen; it is mentioned, however, that the cost of re-lining the brakes with ferodo is considerable, being 450 to 500 francs per month.

The Tarn Departmental Railways have in service two 45-H. P. and one 50-H. P. Renault Scemia rail cars, the latter being built in 1928 for metre gauge.

The former have four monobloc cylinders and one driving axle, the latter have four cylinders in pairs and two driving axles. Transmission is by cardan shaft on to the trailing axle, and in the rail cars with two driving axles the leading axle is driven by a gear on the longitudinal shaft of the first section of the cardan shaft.

The rail cars have a foot brake, hand brake and air brake.

Their weights are 10.3 and 11.4 t. (10.1 and 11.2 Engl. tons) respectively empty and 13.3 and 14.4 (13.1 and 14.2 Engl. tons) loaded; they provide 44 and 51 places respectively and 29 seated and 15 standing, or 1 000 kgr. (2 200 lb.) of luggage, and 21 seated and 30 standing, or 1 500 kgr. (3 300 lb.) of luggage.

Their length, excluding buffers, is 10.40 m. (34 ft. 1 1/2 in.), wheel base 3.60 m. (11 ft. 10 in.), length of body 9.40 m. (30 ft. 10 in.) and width overall 2.30 m. (7 ft. 6 9/16 in.).

The fuel consumption is 35 litres and 47 litres respectively of petrol per 100 km. (12.3 and 16.6 British gallons per 100 miles), and 2.5 and 3.9 litres (0.88 and 1.38 British gallons) of oil.

They are operated by two men, a driver and guard. There are two driving compartments, one at each end.

The Paris, Lyons, & Mediterranean Railway in 1927, put into service two petrol rail cars on their Algerian lines; they have ordered two others from Messrs Renault for their French lines.

The former, for their 1.055 m. (3 ft. 5 3/8 in.) gauge, have six cylinders, 110 mm. (4 5/16 inches) bore, 140 mm. (5 1/2 inches) stroke, developing 60 H. P. at 1 600 revolutions per minute. The carburettor is automatic, giving a perfectly proportioned mixture of air and petrol under all conditions, ensuring immediate starting from cold by means of a suitably adjusted pilot jet.

The clutch is of the dry multiple disc type, the discs being of steel and bronze. The number of discs is such as to allow the clutch to operate with a relatively small pressure per unit surface, so that the wear is negligible and easy starting is ensured.

The gear box gives four speeds forward and one speed reverse. The reverse gear, being only used for shunting at stations, has the same ratio as the first forward gear.

The rear wheels are driven by a live axle in a cast steel casing. To ensure silent running, direct drive is provided to the axle, the necessary speed reduc-

tion being carried out by a double train of gear wheels in the axle casing.

The engine may be started by hand or by electric dynamo, which continuously charges the battery and produces current for lighting.

There is only one driving compartment, at the leading end.

In order to give a good view of the road, the rail car is driven like an automobile, that is to say, the driver is seated on the left of the engine. Various controls are conveniently arranged and the control gauges are well in view. The engine is stopped when the car stops and is disengaged when running down gradients of more than 1 in 143, except in case of failure of the brake, when the engine is engaged to act as a brake.

The rail car has a bogie at the leading end, the trailing axle being on a Bissel truck jointed to the main frame by means of a large spherical pivot, the vehicle being driven or held back by this pivot.

The wheel base is 6.60 m. (21 ft. 8 in.) and the length, excluding buffers, is 11.86 m. (38 ft. 11 in.).

46 seats are provided, 8 being second class and 38 third class.

There is, moreover, standing room for 6.

The weight of the vehicle empty is from 14 to 14.6 t. (13.8 to 14.4 Engl. tons) in working order.

The rail car is provided with two independent brakes :

1.— An internal expanding brake operating on the transmission and controlled by a foot pedal; the brake power may instantaneously attain a value approximating the weight on the rear axle.

2.— A screw brake operating brake blocks on the wheels.

A whistle and a Klaxon horn are fitted for signalling purposes.

The maximum speed of the rail cars is 50 km. (31 miles) per hour. They are used either with or without trailers weighing 8.4 t. (8.3 Engl. tons) over a line with heavy gradients up to 1 in 50, one such gradient having a length of 2.3 km. (1.4 miles). The total rise in altitude is 295 m. (970 feet); the line which has a length of 57 km. (35.4 miles) is covered in 2 hours, and about 12 minutes lost time may be made up. The speed is as low as 20 km. (12.4 miles) per hour on gradients of 1 in 50; the stations are 5 to 10 km. (3.1 to 6.2 miles) apart.

A rail car makes one outwards journey one day and returns the following day, the daily distance being 60 km. (37.3 miles); 1 1/2 hours is allowed for repairs and lubrication by the driver each time the car returns to its shed, that is, after running 120 km. (74.6 miles). When one rail car is out of service, the other car makes the double journey.

All working parts are gone over every 10 000 km. (6 200 miles), and in addition, the engine is inspected, valves are ground in and the oil in the sump changed, every 3 000 km. (1 860 miles).

The speed attained is not considered sufficient, and the Company are considering the purchase of Diesel rail cars, both for standard and narrow gauge lines, capable of hauling a total weight of about 100 t. (98.4 Engl. tons) at a speed of 100 km. (62 miles) per hour on the level and 30 km. (18.0 miles) on a gradient of 1 in 50.

The rail car is operated by one man; the guard is, however, able to stop the car, there being access from the brake van to the driving compartment.

The more powerful rail cars which it

is proposed to introduce will run without trailers and be able to convey 100 passengers with their luggage; there will be 6 first class seats, 12 second and 82 third. It is also intended to use a rail car as a locotractor hauling a brake van, one composite coach accommodating 12 first class and 24 second class passengers and 2 third class coaches each accommodating 56 passengers. Communication between the brake van and the power unit will be necessary in this case.

These motor trains will have 2 driving compartments each complete with all controls to avoid turning.

The rail cars are stabled at engine sheds which have sufficient accommodation to keep them apart from the locomotives.

The staff who operate these vehicles are fitters accustomed to internal combustion engines and young drivers who have been suitably instructed.

There is nothing in particular to mention as regards defects, other than that engines which are worked too close to their maximum capacity frequently break their crank cases.

The rail cars which the Paris, Lyons & Mediterranean Railway has ordered for service in France will have two 4-wheel bogies, with six-cylinder engines developing 110 H. P. at 2 200 revolutions per minute and will accommodate 57 passengers, namely, 12 first class and 45 third class. There will be a luggage compartment of 6 m² (65 sq. feet) area and a driving compartment at each end; the tare weight will be 23 t. (22.6 Engl. tons), that is, 400 kgr. (880 lb.) per passenger.

The 3rd class compartment will have 4 seats which can be shut off by means of a longitudinal partition for the use, where necessary, of the Postal Department.

They will be fitted with a brake acting on the wheels operated from either driving compartment, either by a hand wheel or by compressed air by means of a driver's brake valve, and also with a foot brake operating on the transmission.

They will have a compressed air whistle, be heated by the exhaust gases and be lighted electrically from a dynamo.

They will have 4 speeds in either direction, namely, 12, 24, 38 and 64 km. (7.5, 15, 23.6 and 39.8 miles) per hour on the level. Trailers will not be hauled. They will be operated by Operating Department staff.

The Company hopes that these rail cars will prove suitable for replacing the ordinary trains running at infrequent intervals on lines of easy gradients. Up to the present they have no satisfactory rail cars.

The *Italian State Railways* have put in service an internal combustion rail car (fig. 9) accommodating 45 3rd class passengers and weighing only 17.5 t. (17.2 Engl. tons), that is 400 kgr. (880 lb.) per passenger.

They have two bogies, the inner axles of which are driving axles.

These axles are driven by means of cardan shafts and bevel gearing.

Each bogie (fig. 9 *bis*) is fitted with a bolster. The body, which is of sheet metal in order to obtain sufficient strength with a minimum of weight, is carried on each bolster by 4 coiled springs.

The bolsters also carry longitudinal members which support the bed plate on which the engine and gear box are mounted. These longitudinal members are also supported on rollers resting on

Fig. 9. — Italian State rail motor coach.

the inner headstokcs of the bogie frames.

The bed plate carrying the engine is thus supported independently of the body, which prevents the latter being subjected to vibration. To overcome the increase of weight on the inner axles resulting from this arrangement, the body of the vehicle is connected to the engine bed plate by four coiled springs.

The transmission includes a disc clutch and a gear box, giving four speeds in both directions, namely, 8, 16, 25 and 40 km. (5, 10, 15.5 and 25 miles) per hour at 1 000 revolutions per minute; the drive is by cardan shaft to the driving axles. An electric starting motor, two dynamos for charging the batteries, an air compressor for the Knorr brake and whistles and an electro-mechanical brake taking current from the accumulator and acting on a drum keyed to the driving shaft are provided.

The engine has six cylinders 140 mm. (5 1/2 inches) diameter and 160 mm. (6 5/16 inches) stroke, developing 100 H. P. at 1 000 revolutions per minute.

Forced lubrication is provided by centrifugal pump.

Radiators are mounted on the roof at either end, the amount of air passing being regulated by rotary valves. In

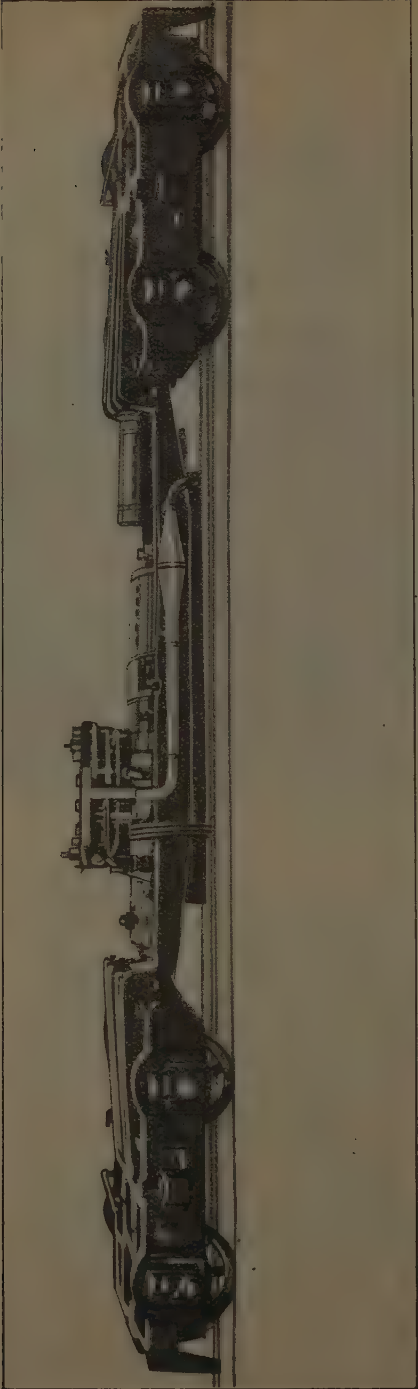

Fig. 9bis. — Italian State Railways. — Chassis of rail motor coach.

Winter the hot water is used for heating the coach and is passed through coils of pipe arranged in the interior.

The carburettor is designed to use both petrol and heavy oil and will be described later.

There are four reservoirs for fuel, two with a total capacity of 160 litres (35 British gallons) in the roof for heavy oil and two others with a total capacity of 120 litres (26 British gallons) under the floor for benzine. These latter are at a lower level than the carburettor; an auxiliary reservoir of about 5 litres (1.1 British gallon) is provided at a suitable height, and the benzine is drawn up by the engine by a connection taken from the induction pipe.

The ignition is by two independent high tension magnetoes and a double set of sparking plugs.

There is a driving compartment at each end. The car is operated by one specially trained employee of the Motive Power Department. The guard is able, if necessary, to stop the train and can drive it at caution to the nearest station.

Trials have been carried out on a line 101 km. (62.8 miles) long, a considerable part of which has gradients up to 1 in 37.

The average speed was 29 km. (18 miles) per hour, stops being 6.3 km. (3.9 miles) apart. On a line 78 km. (48.5 miles) long, with short gradients of 1 in 166, the average speed with a 31-t. (30.5 Engl. tons) trailer was 31 km. (19.3 miles) per hour, the distance between stops being 5.5 km. (3.4 miles). Finally, on a run of 35 km. (21.7 miles), with a maximum gradient of 1 in 38 with a trailer weighing 11 t. (10.8 Engl. tons) and distance between stops 7 km. (4.4 miles), an average speed of 28 km. (17.4 miles) per hour was obtained. A

speed of 40 km. (25 miles) per hour was maintained on gradients up to 1 in 29 without a trailer. On the level and on easy gradients a speed of 50 km. (31 miles) per hour was obtained with an engine speed slightly above the normal.

The Italian State Railways are also about to carry out some tests with Diesel locomotives and Diesel electric rail cars.

The Belgian National Railway Company tested, in 1929, a Diesel rail car constructed at the Maybach works, of which particulars are as follows :

- Maximum power, 150 H. P.
- Maximum revolutions per minute, 1 350.
- Four speeds, approximately 10, 20, 40 and 60 km. (6.2, 12.4, 25 and 37.3 miles) per hour.
- Length, excluding buffers, 21.040 m. (69 feet).
- Length of body, 19.740 m. (64 ft. 9 in.).
- Diameter of wheels, 1 m. (3 ft. 3 3/8 in.).
- Wheel base of bogies, 3.50 m. (11 ft. 6 in.).
- Distance between bogie centres, 13.30 m. (43 ft. 8 in.).
- Weight in working order, 38 t. (37.4 Engl. tons).
- Number of places, 74 seated, 15 standing. A modification of the internal arrangement will allow 90 seats and a luggage compartment.

The body of the coach is of sheet metal and is carried on two bogies, one driving and the other carrying.

The engine has six cylinders driving a crank shaft arranged longitudinally; the primary shaft of the gear box is driven through a shaft with universal joints at each end, the primary shaft carrying four spur wheels. The secondary shaft of the gear box carries four spur wheels constantly in mesh with the wheels of the primary shaft, each being provided with a disc clutch operated by oil pressure; the clutch of any one pair of wheels may be brought into operation, the other wheels being automatically declutched. Provision is made so that it is only possible to engage the clutch of the wheel suitable for the particular speed of the car.

At the end of the secondary shaft is a bevel wheel engaging with two bevel wheels mounted freely on a jack shaft, a dog clutch is fitted on the jack shaft between the bevel wheels so that it can engage with either wheel and drive the car in either direction. A jack shaft drives the axles of the motor bogie by cranks and rods.

The crank shaft also drives a three-stage compressor; the air, at a pressure of 110 atmospheres (1 564 lb. per sq. inch), is stored in three reservoirs after passing through a reducing valve which reduces the pressure to 80 atmospheres (1 140 lb. per sq. inch). These reservoirs provide air for starting. A branch, between the reducing valves and the reservoirs, feeds at 8 atmospheres (114 lb. per sq. inch.) by means of a second reducing valve, the reservoir of the automatic continuous brake. Finally, air at 80 atmospheres (1 140 lb. per sq. inch.) is taken for fuel injection. The fuel is a mixture of air and oil, which enters the cylinders at the end of the compression stroke when the pressure is 35 atmospheres (498 lb. per sq. inch) and the temperature 600° C. (1 112° F.) so that spontaneous ignition takes place.

This method of « dynamic » injection allows a larger orifice to be used than with the solid injection type and gives less risk of failure.

A needle valve is placed in the orifice so that the driver can regulate the oil

supply and also remove any obstruction. Admission is limited to 10 % by the to and fro movement of an annular needle valve concentric with the former.

Lighting is by electricity, current being provided by a dynamo mounted on the engine shaft.

Cooling water is pumped through a radiator mounted on the roof, fitted with an electric fan; this water may, if required, be passed through pipes inside the coach for heating purposes.

The tests were made using gas oil as fuel at a cost of 0.60 fr. per litre (2.72 fr. per British gallon).

The engine and gear box, which is carried on the driving bogie, is independent of the body. The driving bogie may be taken out and replaced by another in a few hours.

The rail car is fitted with the automatic Westinghouse brake; the brake may also be operated mechanically by means of a counterweight.

The car is operated by one man, being provided with a dead man's handle. There is a driving compartment at each end.

The cost of the rail car was 1 160 000 fr.

Tests have taken place both on level lines and lines with gradients of 1 in 63 or 1 in 40 over 12 km. (7.5 miles). Speed was maintained at 67 km. (41.6 miles) per hour with two trailers weighing 27 t. (26.6 Engl. tons) on the level (200 to 240 seats in the train), and between 45 and 55 km. (28 and 34.2 miles) on gradients of 1 in 63 with one trailer.

The consumption of gas oil averaged 62 kgr. and lubricating oil 760 grammes per 100 km. (220 lb. and 2.7 lb. per 100 miles respectively).

During the tests the rail car ran 2 062 km. (1 280 miles). The results being considered satisfactory, the Company have ordered three rail cars of the above type.

* * *

The importance of the question dealt with in this report appears to vary widely on different railways, being dependent on the number of trains and train-kilometres which, with regard to the frequency of their service, can be economically operated by special forms of motive power. The extent to which this can be done is shown by the number of these trains and train-kilometres which can be effectively worked by these means.

The following table gives some information received on this point.

RAILWAY.	Paris, Lyons and Mediterranean.	Paris-Orleans.	French Nord.	French State.	Italian State.	Belgian National Railway Company.
Daily number of trains which can be worked by special forms of power.	194	304	Under investigation; few lines have sufficiently light traffic for the use of rail cars to be practical.	...	...	148
Average passengers	...	35		...	...	60
Corresponding train-km. (train-miles).	4 042 (2 512)	12 100 (7 520)		...	...	2 370 (1 473)

RAILWAY.	Paris, Lyons and Mediterranean.	Paris-Orleans.	French Nord.	French State.	Italian State.	Belgian National Railway Company.
aily number of trains which can be effectively worked by special forms of power.	...	16	29	...	427 (1)	148 (2)
verage passengers	...	30	...	...	60	60
orresponding train-km. (train-miles).	...	803 (499)	472 Excluding trains for Company's workmen.	...	21 034 (13 070)	2 370 (1 473)
otal daily number of trains .	1 968	379	...	...	...	2 456
verage passengers.	102	43	..	...	...	152
orresponding train-km. (train-miles).	173 316 (107 695)	16 867 (10 481)	...	...	230 000 (142 920)	109 084 (67 783)

(1) Of which 425 are by light steam locomotives, and two by rail cars [34 train-km. (21.1 train-miles], average interval 10 minutes).
(2) By light steam locomotives.

The Italian State Railways and the Belgian National Railway Company appear from this table to make the largest use of special means of traction, but this refers to the use of light steam locomotives, and the other railways have not given any information on this point. The French Nord and State Railways are those which have the largest number of rail cars in service, and of the railways which have given detailed information of the average use made of the trains, it is the Paris-Orleans which is shown as having the greatest scope for the use of motive power of this kind.

On the majority of large railways, these possibilities are restricted because of the great difference which exists between the average and maximum numbers of passengers on the trains. The stock forming a heavily loaded train often has to return with very few passengers, but the same train has to be worked back so that it may be used later, and the use of a light train for the light load is therefore out of the question. Further, in order to arrange engine workings, it is often necessary to use them on a train which could be worked by a less powerful engine.

Obviously economy is only possible if the use of the light forms of power allows the complete withdrawal of the more powerful engines.

The Belgian National Railway Company contemplates the use of rail cars :

a) on branch lines which serve regions in which the traffic is unimportant and not likely to be developed in the immediate future and which are not adjacent to any important centre. The traffic in this case is almost entirely station to station traffic, and on these lines it may in cases be possible to work the service with rail cars only;

b) on branch lines connecting with an important centre on which the traffic is

capable of development by means of a more frequent service;

c) on certain sections of main lines where the local traffic is small.

The density of traffic on important lines does not as a rule allow a sufficiently numerous service of rail cars to meet the demands of the public, without having to double the track. At most, if one is merely content with introducing rail cars between the ordinary trains, the traffic will be divided between ordinary trains and the rail cars, and the capacity of the latter will soon become insufficient without any particular increase in the total traffic.

In some cases, however, certain sections of these lines may be found where the local traffic is light, as on branch lines,and it may be possible to substitute for the stopping trains rail cars which would then act as collectors or distributers for the through trains.

The number of seats necessary in passenger trains carrying few passengers is estimated :

by the Paris, Lyons & Mediterranean Railway at 132 places (that is 16 first, 18 second and 100 third);

by the Paris-Orleans at 40 places (that is 6 first, 6 second and 34 third);

by the Est at 136 places, that is 16 first, 20 second and 100 third;

by the French State at 81 places.

by the Italian State Railways at 100 to 150 places, and by the Belgian National Railway Company at 150 places.

On the majority of railways, the use of rail cars running without trailers is extremely rare. The use of light powered rail cars with a small number of places therefore does not appear to have a very wide scope.

Information on this point received for the rail cars which have been mentioned may be summarised as follows : « Steam rail cars on the French Nord : 84 places, of which 26 are standing. — A trailer weighing 12 t. (11.8 Engl. tons) accommodating 60 passengers may be hauled on fairly level lines.

Maximum speed 60 km. (37.3 miles) per hour.

Sentinel steam rail cars on the Paris-Orleans Railway : 56 places.

French State Railways, internal combustion rail cars : 20 places; these are capable of hauling, at 50 km. (31 miles) per hour, on the level, 3 trailers of 10 t. (9.8 Engl. tons) each accommodating 70 passengers, or two 10-t. trailers on a gradient of 1 in 100 at 30 km. (18.6 miles) per hour.

The Paris, Lyons & Mediterranean rail cars on order : 57 places, developing 110 H. P. at a speed of 64 km. (39.8 miles) per hour; no indication given as regards trailers.

Internal combustion rail cars, Italian State Railways : 45 places, 110 H. P., maximum speed 40 to 45 km. (25 to 28 miles) per hour, one trailer.

Diesel rail car on trial on the Belgian National Railways : 90 places, 150 H. P., capable of taking one trailer weighing 27 t. (26.6 Engl. tons) on lines with heavy gradients at 50 to 55 km. (31 to 34.2 miles) per hour, or two trailers of 27 t. (26.6 Engl. tons) on a level line at 60 km. (37.3 miles) per hour or more.

Rail cars for narrow gauge have been omitted from this summary.

For a number of the internal combustion rail cars, the speed appears rather low.

* * *

The sable on pages 168-169 summarises the information received as regards working expenses.

It will be seen that there is an economy per train-km. in favour of the rail cars, due to the power of the engine being more in accordance with the load hauled than in the case of a light locomotive, and due to the reduction in dead weight.

If an internal combustion rail car is economical, although using a much more expensive fuel than a steam engine, it is because no fuel is lost while standing or for lighting up, both important factors for a steam engine. Moreover, the thermal efficiency of an internal combustion engine is much higher than that of a steam engine.

Several railways are making efforts to use cheaper fuel than petrol, particularly, as we have seen, the Paris-Orleans Company and the Italian State Railways. The Belgian National Railway Company is for this reason turning to the Diesel engine, as are also the Italian State Railways and the Paris, Lyons & Mediterranean for its African lines.

The Italian State Railways have tried to use in their rail cars, in addition to benzine, a heavy petroleum residue having the following characteristics : specific gravity 0. 868; Pensky-Martens flash point 82° to 83° C. (179.6° to 181.4° F.); calorific value 10 902 (19 600 B. T. U. per lb.); volatiles 37 % at 310° C. (590° F.) 99 % at 350° C. (662° F.); total sulphur 0.15 % by weight. This oil can be bought at a cost of 1/6th to 1/7th of that of benzine. This fuel has been used by means of the Aliverti carburettor, which has the following characteristics :

a) the proportion of cheap fuel to benzine is automatically regulated without any adjustment by the driver, who has a tendency to use too much benzine in order to give the engine greater flexibility;

b) it allows a very small quantity of benzine to pass continually into the combustion chamber which prevents the engine from stopping on account of insufficient fuel, and enriches the mixture, this reducing the disadvantages arising from the exclusive use of heavy oil.

By the use of this carburettor, the fuel cost has been reduced by one half on tests with a motor car engine of 25 to 35 H. P. It is true that these tests have shown that the power of the engine was reduced by the cheaper fuel (mixture of benzine and oil), but not to a serious extent.

As a result of these tests, the 100-H. P. rail car under test on the Italian Railways has been fitted with the carburettor in question (fig. 10).

It operates as follows :

When the throttle is in the closed position, the butterfly valve A remains slightly open, allowing a small amount of vaporised benzine to pass. The valves B and C are closed. The engine is thus running on benzine while idling. In opening, the throttle valves B and C are first operated, valve A remaining in its initial position. The engine continues to receive its mixture of benzine from the central group A, and the suction produced through B and C lifts the automatic air inlets and draws benzine and oil contained in the float chambers to the jet; the benzine, however, has to pass by a ball valve, while the oil passes through a coil of pipe S encircling the tube T through which part of the exhaust gases pass. The relative resistances are so arranged, that while the engine is cold, no oil reaches the jet and only benzine is used, this lifting the ball *e*. When the engine has warmed up sufficiently for oil to be used, the coil and pipe S being heated, the resistances to

EXPENDITURE (in francs) for		French State.		
		Internal combustion rail car.	Steam economic locomotive.	Steam rail car
Fuel	per train-kilometre (per train-mile)	1.15 (1.85)	2.37 (3.81)	0.92 ((1.48)
	per tonne-kilometre (per Engl. ton-mile)	0.034 (0.056)	0 0337 (0.0550)	0.0196 ((0.0320
Lubrication	per train-kilometre (per train-mile)	0.15 (0.24)	0.02 (0.032)	0.05 (0.08)
	per tonne-kilometre (per Engl. ton-mile)	0.004 (0.0065)	0.003 (0.005)	...
Water	per train-kilometre (per train-mile)	...	...	...
	per tonne-kilometre (per Engl. ton-mile)	...	...	...
Wages of footplate staff.	per train-kilometre (per train-mile)	0.43 (0.69)	0.43 (0.69)	1.15 (1.85)
	per tonne-kilometre (per Engl. ton-mile)	0.013 (0 021)	0.006 (0.010)	...
Cleaning and maintenance.	per train-kilometre (per train-mile)	0.58 (0.93)	0 50 (0.80)	0 63 (1.01)
	per tonne-kilometre (per Engl. ton mile)	0.019 (0.030)	0.007 (0.011)	...
Total	per train-kilometre (per train-mile)	2.31 (3.72)	3.32 (5.34)	3.34 (5.38)
	per tonne-kilometre (per Engl. ton-mile)	...	...	...
Cost of	petrol	1.70 fr. per litre (7.73 fr. per Brit. gallon).	...	...
	coal	...	...	...
	oil	4.75 per kgr. (2.15 fr. per lb.)	...	...
Cost of rail car		117 000 fr.	...	220 000
Life for purposes of depreciation		10 years.	...	40 year
Remarks		...	...	(1) 7.75 kgr. per km. (27 per mil 2.10 kgr. per 100 km. (per 100 m

	Paris-Orleans.				Belgian National Railway Company.
n economic omotive.	Tank locomotives.	Sentinel rail car.	Renault rail car (narrow gauge).	Most economical locomotive.	Diesel rail car.
...	1.72 (2.76)	0.50 (0.80)	0.70 (1.13)	1.76 (2.83)	...
...	...	...	...	...	...
...	0.04 (0.064)	0.09 (0.145)	0 10 (0.16)	0.04 (0.064)	...
...	...	...	...	...	...
...	0.04 (0.064)	0.01 (0.016)	...	0 04 (0.064)	...
...	...	...	...	...	...
...	0 57 (1) (0.91)	0.57 (0.91)	0.25 (0.40)	1 04 (1.67)	...
...	. .	...	...	...	...
...	0.90 (1.45)	1.32 (2.12) (estimated)	0.338 (0.544)	0.90 (1.45)	...
...	...	...	...	...	...
7.25 (11.66)	3.27 (5.26)	2 492 (4.010)	1.386 (2.230)	3.793 (6.104)	...
...	0.029 (0.047)	0.077 (0.125)	0.0871 (0.1424)	0.0336 (0.0549)	...
...	. .	...	2.20 per litre. (10 fr. per Brit. gallon).	...	...
...	160 fr. per ton.	180 fr. per ton.	...	...	...
...	Cylinder oil, 3.80 fr. per kgr. (1.72 fr. per lb.)	(Superheater oil, 5.50 per kgr. 2.50 fr. per lb.)	4 fr. per kgr. (1.81 fr. per lb.)	...	...
...	70 to 80 000 fr. pre war.	282 000 fr. in 1925.	107 000 fr. in 1924.	...	1 160 000 Belgian francs.
...	...	20 years.	12 years.	...	20 years.
...	Wages 80 fr. per day.	...	Wages : 11 000 to 12 000 fr. per year. Narrow gauge, not comparable	...	...

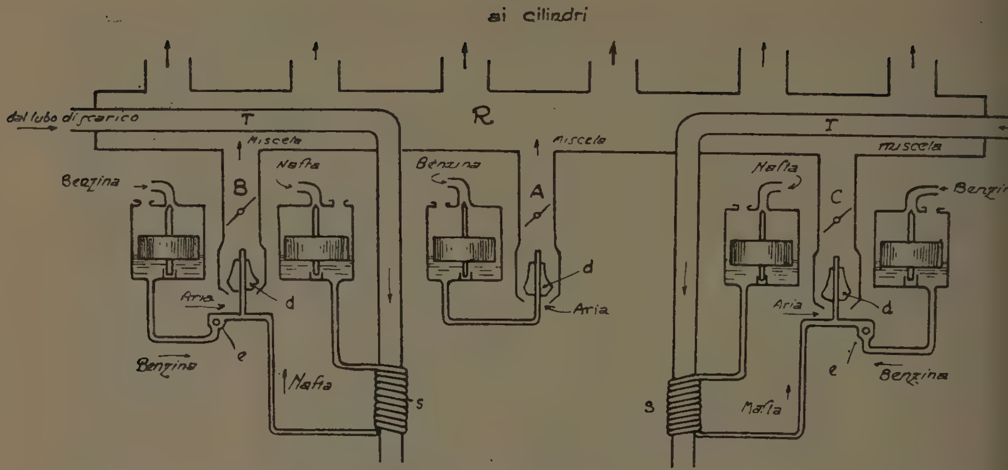

Fig. 10. — Aliverti carburettor.

Explanation of Italian terms: Ai cilindri = To the cylinders. — Aria = Air. — Benzina = Benzine. — Dal tubo di scarico = From exhaust pipe. — Miscelo = Mixture. — Nafta = Naphta.

the flow of oil decrease, and it arrives at the jet along with the benzine, which still has to lift the ball *e*.

When the engine has reached its normal temperature with full load, the amount of benzine used decreases and becomes practically negligible.

If the throttle is opened still further, since valves B and C are half open, valve A also begins to open, and when full power is being developed, benzine from the central jet enriches the mixture of oil from the outer jets. The mixture passing to the cylinders is preheated by the two pipes T, which are connected to the exhaust manifold E, this passing through the inlet manifold and finally heating the pipe coils S.

In short, the system consists in permanently feeding a small quantity of benzine corresponding to minimum power. The quantity of benzine is also automatically increased by the outside jets when the engine is cold, as on starting up, and by the centre jet to obtain increased power when the throttle is full open.

The most complete solution of the fuel question is afforded by the Diesel engine. Unfortunately Diesel engines are expensive, and the interest and depreciation charges render petrol engines a more economical proposition unless considerable mileage is run. In determining what this mileage is, the length of life on which sinking fund charges are based is an important matter. However, the use of rail cars on the railways dealt with is of too recent date to allow this life to be determined with certainty. The tests taken in hand by the Italian State Railways therefore appear interesting, if they enable the petrol engine to compete on more favourable terms with the Diesel engine.

It may be pointed out that when rail cars are used on an intensive service, the disadvantages of steam, namely, necessity of using coal while standing and

for lighting up, become relatively less important compared with internal combustion engines. The steam rail car or the light locomotive may offer the best solution in many cases.

* * *

Another economy which may result from the use of internal combustion cars is the possibility of their being handled by one man. We have seen that the French State and the Paris-Orleans also only employ one man on their light steam locomotives. It would appear, however, that on lines where the traffic is of any importance, only internal combustion rail cars can be operated with sufficient safety by one man. In every case the adoption of a « dead man's handle » is to be recommended.

On the subject of the training of rail car drivers, no difficulties have been mentioned. Their wages are less than those of a locomotive driver.

No outstanding facts arise as regards maintenance and repairs. The internal combustion rail cars are of types differing as regards the cylinders, carburettor and transmission. The difficulties mentioned are generally of a temporary nature or refer to the period when first put into service. These are difficulties which can be overcome, such as fractures of badly designed parts, breakage of pipes through vibration, as mentioned by the French State Railways. Rather a large number of failures took place initially on the narrow gauge rail car of the Paris-Orleans, this being one of the first completed by the makers. The use of ferodo brake linings was expensive, being 400 to 500 fr. per month, while there are also a number of failures with the Sentinel rail car. The Paris-Orleans cannot yet say what the maintenance costs of this car will be.

As regards annual mileage, the French State quote 15 500 km. (9 630 miles) for petrol rail cars as against 19 500 (12 120 miles) for light locomotives; the French Nord quote 30 000 km. (18 640 miles) for its steam rail cars, this being the same as for locomotives; the Paris-Orleans quote 30 000 km. (18 640 miles) for the Sentinel rail car and 45 000 to 50 000 km. (28 000 to 31 000 miles) for the petrol rail cars as against 70 000 (43 500 miles) for light locomotives; the Italian State quote 12 000 km. (7 460 miles) for petrol rail cars as against 25 000 (15 530 miles) for locomotives.

* * *

The conclusions to be drawn from all the foregoing, as far as concerns the railways dealt with, is that they are still in an experimental stage as regards the use of economical methods of traction for trains on branch lines with light traffic and for occasional trains on some important lines. It may be noted that there is a marked tendency to use internal combustion and Diesel rail cars, but steam traction, either by light locomotives of steam rail cars, is still the most usual method.

QUESTION XII. — B.

Use of special tractors for shunting in smaller yards and for certain work in large yards.

Locotractors.

The following table summarises the information on locotractors in service on the different railways.

RAILWAY.	Type.	Number in service.	Horse power.	Number of speeds.	Weight. in metric (English) tons.	Date of purchase.
North of Spain . .	(with capstan).	2	50	4 in each direction	9 (8.85)	1926
Paris, Lyons & Mediterranean.	Baudet, Donon, Roussel. (with capstan).	1	100	12	30 (29.5)	1927
Paris-Orleans . . .	ditto.	1	do.	...	...	1925
State	ditto.	6	do.	...	...	1924
Est	ditto.	2	40	12	...	1923
Nord	ditto.	4	do.	...	...	1922
State	ditto.	3	40 to 50	...	20 and 22 (19.7 and 21.7)	1925
Paris, Lyons & Mediterranean.	Berliet (with capstan).	25	26 to 33	...	15 to 16 (14.7 to 15.7)	1924
French Nord . . .	Moyse (without capstan)	4	90	...	...	...
	Schneider (without capstan).	4	55	...	...	...
	Steam locotractor (with capstan).	4	...	..	...	...

A.— Petrol locotractors.

The Baudet, Donon, Roussel 100-H. P. locotractors, of which both the Paris, Lyons & Mediterranean and the Paris-Orleans possess one and the State Railways six, have been found capable on the latter of replacing six-coupled steam locomotives unit by unit.

They weigh 30 t. (29.5 Engl. tons) and can haul in service loads exceeding 500 tons at a speed of 15 to 18 km. (9.3 to 11.2 miles) per hour. The engine has eight cylinders arranged in V formation, the clutch being of the disc type, and the gear box having 12 speeds, namely, 1 to 60 km. (0.74 to 37.3 miles) per hour, the final drive to the axle being by chains.

Figure 11 gives a view of this unit taken from an article by Mr. Polart, Technical Engineer of the State Railways (*Revue Générale des chemins de fer*, March 1926). The following information is taken from this article.

The locotractors are fitted with hand brake, and direct and automatic air brake, and are provided with electric lighting.

The engine is started by compressed air; the capacity of the petrol tank (250 litres [55 Brit. gallons]) is sufficient for 24 hours without refilling.

The locotractors are operated by one man.

All the controls are arranged in a centre cab. Those which are constantly used during shunting operations (clutch, change gear lever, throttle and air brake) are duplicated for operation from either side of the cab. The speed indicator, air and oil pressure gauges, engine cut-out switch and lighting switches are

Fig. 11. — View of a Baudet-Donon 100-H. P. locotractor.

mounted on a panel and are clearly visible to the driver.

96 hours work are done daily on the State Railways by these tractors, for which 6 are required, 2 being in reserve; one of the 2 reserve tractors is kept ready in working order at the shed, the other may be out of service for heavy repairs.

These engines, which are only used for station shunting, are operated by the traffic department staff in accordance with the practice on the French railways in this respect, but the duties of the drivers are strictly limited to shunting work and include no repairs. Each locotractor in service is operated by a set of three men, working 8 hours without a break.

Special attention has to be given to maintenance, as an internal combustion engine is more liable to failure than a steam engine; it is liable to stoppages, but these are as a rule of short duration. It is therefore necessary to arrange that the working parts should be frequently inspected and immediately repaired. At Paris St. Lazare, where the six 100-H. P. locotractors of the State Railways are used, running repairs are undertaken by the Traffic Department, the Mechanical Engineer's or Motive Power Department only dealing with heavy repairs. A special shed has been provided (figs. 12 and 13) with an inspection pit capable of taking two locotractors, a petrol pump and a small store with the necessary tools and spare parts.

The locotractors in service are re-filled with petrol once every 24 hours, this only taking a few minutes. At the same time, special mechanics satisfy themselves that all parts are functioning correctly and attend to reports made by the driver. The necessary adjustments are thus made, the locotractor, if necessary, being placed over a pit. If the repairs necessitate withdrawal from service, the spare locotractor is used.

The re-fuelling and daily inspection take about 40 minutes.

The petrol reservoir at the shed has a capacity of about 18 000 litres (3 960

Fig. 12. — Fuelling the locotractors.

Fig. 13. — Inside view of locotractor shed.

British gallons) and consists of three tanks placed underground. The petrol is delivered in tank wagons which are emptied by gravity; a special meter records the petrol received. Petrol is distributed to the locotractor by means

Fig. 14. — Repair shop for locotractors.

of a small rotary electrically driven pump which forces the petrol through a special regulator and meter to a flexible pipe terminating in a cock which is placed in the petrol tank. The petrol is thus entirely enclosed while being handled and the loss is reduced to a minimum. The plant is fitted with the regulation devices for protection against fire (sand and chemical extinguishers). The shed measures 20 m. × 6 m. (65 1/2 × 19 feet) and has a pit 15 m. (49 feet) long and good natural lighting is provided. Artificial lighting is provided by 200 candle power lamps and plugs for portable lamps are installed on the walls and in the pit. A 1 000-kgr. (1-ton) hoist on a cross beam allows heavy parts to be moved. The workshop (fig. 14) has a floor space of about 30.2 m² (325 sq. feet); the stores 20.3 m² (219 sq. feet). The machine tools are arranged in the shop so as to allow sufficient space in the middle for work on an engine or gear box.

A special staff is employed under a technical foreman, who is also in charge of the drivers and who is assisted by an assistant foreman. A specially trained motor mechanic is attached to the shop and carries out all the repairs and adjustments; two fitters are occupied on small repairs and decarbonisation. The total staff of the shop is therefore 5, in addition to the drivers. The hourly running expenses of a locotractor at St. Lazare station were as follows in 1925 :

1.—	Petrol	9.15 fr.
	Oil	0.85 fr.
2.—	Labour	6.70 fr.
3.—	Repairs	1.60 fr.
4.—	Depreciation . . .	4.50 fr.
	Total	22.80 fr.

Comparing this cost with that of steam locomotives, calculated on the same basis,

the locotractors show an economy of 40 %.

It should be noted that these locotractors were put into service at Paris-St. Lazare in order to avoid smoke and steam.

The Paris-Orleans only possesses one 100-H. P. locotractor and do not for the time being propose to extend the use of this type of power. They mention that it necessitates specially trained mechanics thoroughly conversant with the engine and able to carry out a rapid decarbonisation.

The Paris, Lyons & Mediterranean gives the following cost per hour for a 100-H.P. locotractor in 1927 in francs :

1.— Petrol 2 500 (11.42 l. [2.5 British gallons])
Oil 1.48 (0.186 kgr. [0.41 lb.])
Miscellaneous 0.08
2.— Drivers' wages 5.44
3.— Inspection and repairs 3.70 (estimated)
4.— Depreciation on 6 years' life 15.00
Total 50.70 fr.

Baudet-Donon-Roussel tractors of 40 H.P. have been employed on the French Est since 1923 for light shunting and at small stations where not more than 10 wagons as a maximum are dealt with. They are satisfactory as replacing hand shunting or shunting by horses or capstans. They have not sufficient reserve of power to shunt a cut of a large number of wagons and are not satisfactory where this is necessary, as for example in an important station, as shunting then becomes too slow.

They are suitable for handling total weights not greater than 200 tons.

Between stations, when running light, locotractors have a speed of 40 km. (25 miles) per hour and can easily fit in between goods trains. As they can be quickly placed in a siding and take but little space, they do not delay traffic. For taking a few wagons from station to station, they can run from 30 to 35 km. (18.6 to 21.7 miles) per hour if the load is not more than three wagons. The use of these engines for working the traffic to and from stations where this is very light allows the number of stopping freight trains to be reduced, thus enabling more through trains to be run, which is an appreciable advantage on lines with very heavy traffic.

The locotractors consist of a flat wagon 7.40 m. (24 ft. 3 3/8 in.) long, with two axles 3.45 m. (11 ft. 4 in.) apart; the frame of the wagon carries another frame which supports the whole of the mechanism, namely, engine, gear box, reserve gear and driving pinions.

The engine, which has 4 separate cylinders, can develop 40 H. P. at 1 000 revolutions per minute. It is fitted with a governor which limits the revolutions to this amount. Cooling is by thermo-syphon and radiator without a fan. The radiator is connected with the reservoir of 1 200 litres (264 British gallons) and carried at the front end of the wagon, under the floor. Forced lubrication is provided for the crank shaft and splash lubrication for the rods, cylinders and pistons.

The clutch is of the multiple corrugated disc type running in oil, and may be slipped when starting without overheating or wear. It is connected to the gear box by a special coupling, which allows the clutch to be taken down without interfering with the engine or gear box.

The gear box has 12 speeds ranging from 1.5 to 40 km. (0.9 to 25 miles) per hour. Reversing is obtained by a bevel pinion driving bevel wheels on one side or the other.

Both axles are driving axles and are

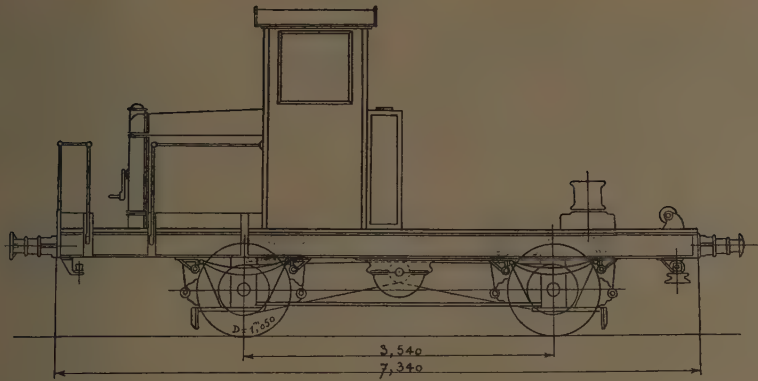

Fig. 15. — Baudet-Donon-Roussel locotractor, French Nord Railway.

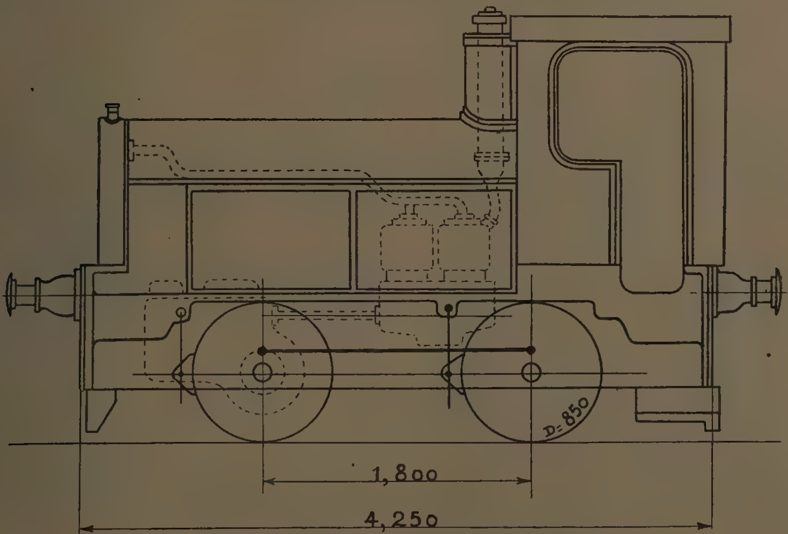

Fig. 16. — Schneider locotractor, French Nord Railway.

driven by roller chains; sanding gear is provided.

An air compressor driven by the engine provides compressed air for the brakes, whistle and for starting the engine.

The various controls are placed in a cab with glass windows, in the centre of the vehicle.

The locotractor is provided with a brake on the transmission and with a brake operating 8 brake blocks on the wheels,

the latter brake can be operated either by the Weshinghouse system or by a hand screw.

Behind the driver's cab, a vertical capstan driven by the motor can produce a tractive effort of 300 kgr. (660 lb.) on the wire rope.

The tractors not in service stand espe-

—	Cylinders.			Revolutions per minute.	Diameter of wheels.	Wheel-ba
	Number.	Diameter.	Stroke.			
Baudet-Donon . . .	4	125 mm. (5 inches).	140 mm. (5 1/2 inches).	1 000	1.050 (3 ft. 5 3/8 in.)	3.540 (11 ft 7 13/32 i
Schneider	4	135 mm. (5 5/16 inches).	170 mm. (6 11/16 inches)	1 000	0.850 (2 ft. 9 1/2 in.)	1.800 (5 ft. 11
Moyse	4	125 mm. (5 inches).	150 mm. (6 inches).	1 450	1.050 (3 ft. 5 3/8 in.)	2.770 (9 ft. 1 i

cially during cold weather in sheds provided for this purpose; a small workshop is attached and a stores containing a stock of the most useful spare parts, a petrol store and a washing down platform.

The purchase price in 1923 was 175 000 fr., and the sinking fund contributions are spread over a life of 10 years. In order to guard against stoppage, one spare tractor is provided for every one in service, which also permits running repairs to be kept up to date.

The consumption per hour is 5.5 litres (1.2 British gallons) of benzol and 0.3 litres (0.07 British gallons) of oil. The tractor is driven by one man, who is head shunter and who receives an additional driving premium of 2 fr. per day over his ordinary salary.

The cost of the shed and lines for stabling the tractor may be estimated at 37 000 fr.

The French Nord Railway uses the Baudet-Donon-Roussel (fig. 15), Schneider (fig. 16) and Moyse (fig. 17) locotractors for shunting in medium size stations for placing wagons in goods sheds and sidings and for attaching or detaching wagons from trains.

The Schneider and Moyse locotractors are not fitted with capstans. The table above gives particulars of the internal combustion locotractors on the Nord Railway.

Shunting is carried out by either *hauling* or *propelling*. The daily distance run is recorded by an instrument carried on the tractor and varies from 15 to 27 km. (9.3 to 16.8 miles).

About 1 to 2 hours are required per day for inspection and repairs, compared with the two hours required for raising steam in a steam shunting engine.

The driver is a member of the traffic department staff, who in addition to his wage of 35 fr. per day, receives an extra

driving premium of 2 fr. per day while driving.

Up to the present no special sheds have been provided, but the Company have decided to build portable sheds which can be easily dismantled if required.

Internal combustion locotractors were introduced in 1922, and their use has

ght, etric lish) ns	H. P.	Type of transmission.	Speeds.	Maximum speed per hour.	Weight hauled on straight level track.
2 .7)	40	By chains.	12 speeds- 1.5 to 40 km. (0.9 to 25 miles).	30 to 40 km. (18.6 to 25 miles).	500 tons at 1.5 km. (0.9 mile). 200 to 250 tons at 7 km. (4.3 miles) per hour. 20 tons at 40 km. (25 miles) per hour.
5 .8)	55	Direct gear drive.	4 speeds- 5 to 16 km. (3.1 to 10 miles).	16 (10 miles).	240 tons at 5 km. (3.1 miles) per hour. 60 tons at 16 km. (10 miles) per hour.
0 .7)	90	Electric and chain.	0 to 25 (15.5 miles).	25 (15.5 miles).	600 tons at 4 km. (2.5 miles) per hour.

been extended to all stations where they can show an economy over shunting engines.

The average cost for locotractors, excluding interest and depreciation, works out at 7 fr. per kilometre (11.20 fr. per mile) and 29 fr. per hour, as follows :

	Per km. (per mile.)	Per hour.
fuel	4 (6.40)	16
lubricating oil	0.75 (1.20)	3
wages	1.25 (2.00)	5
maintenance	1.00 (1.60)	5
	7.00 (11.20)	29

A locotractor at hand may not only save the time an engine occupies in shunting, but also saves the time taken for the engine to run to and from its shed.

A locotractor shunting in a station for 8 hours only saved a whole 8 hour-turn in the working of the engine used to work the station.

On the State Railways, the use of locotractors is extending yearly.

The Paris, Lyons & Mediterranean is also satisfied with the results obtained with its Berliet locotractors, these having 4 wheels and a power ranging from 26.5 to 33.9 H. P., the speed of the engine is from 900 to 1 450 revolutions per minute, this speed being limited by a centrifugal governor which operates to weaken the strength of the mixture. The carburettor, in which the amount of air is mechanically regulated, gives economical running at all speeds. The petrol tanks contain 180 litres (39.6 British gallons).

The engine has 4 cylinders, 110 mm. (4 3/8 inches) bore by 140 mm. (5 1/2 inches) stroke, cast in pairs.

Cooling is by a tubular radiator and

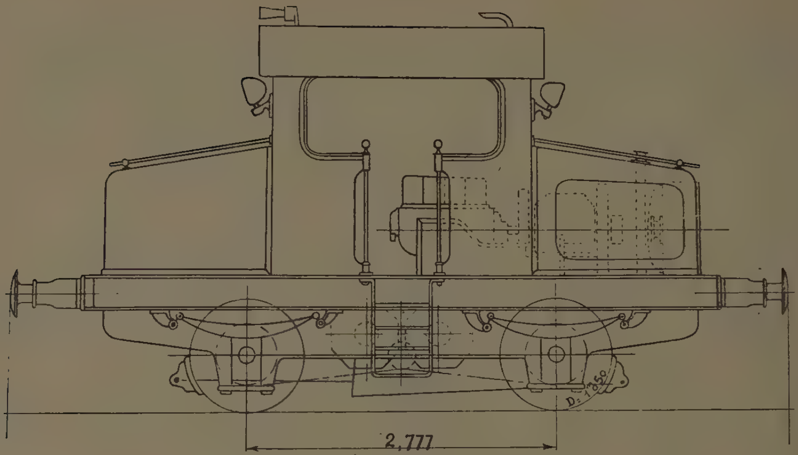

Fig. 17. — Moyse locotractor, French Nord Railway.

fan, and a centrifugal water circulating pump is provided.

The gear box has 4 speeds, while the drive to the wheels is by roller chains.

The clutch is of the multple disc type with alternating steel and bronze discs.

The engine is started up by a starting handle which automatically disengages.

The frame is a rigid structure built up of rolled steel sections and plates.

The locotractors are fitted with two independent brakes, one having segments acting on brake drums, the other being a screw brake operating blocks on the wheels. The former is instantaneous and is as powerful as the brake on the wheels.

Four sandboxes allow sand to be applied for either direction of running.

The driver's cab is open at the sides and has glass windows back and front.

The Berliet locotractors are provided with capstans to move wagons on parallel lines or transversly to that on which the tractor is standing, these capstans being able to exert a pull of 1 400 kgr. (3 080 lb.) at the rim of the drum. The gear lever and clutch of the capstan is provided outside the cab close to the drum, the clutch for the capstan being independent of the ordinary clutch. An accelerator is also provided outside the cab for the use of the men working the capstan.

Four rollers are placed at the corners of the frame to guide the capstan rope.

The weight of the locotractors, including the ballast weight, is 15 to 16 t. (14.8 to 15.7 Engl. tons).

A bell is provided to give warning and lighting is by acetylene.

The tractor is capable of starting on the level and hauling at 3 km. (1.8 miles) per hour a load of 250 tons with couplings initially slack, or 180 tons with tight couplings. It can haul 170 tons at 7 km. (4.4 miles) on the level, or 65 tons at 16 km. (10 miles) per hour, which is its maximum speed.

The cost per hour of shunting with a Berliet tractor in 1927 was 27.15 fr. made up as follows :

Petrol	13.26
Oil	1.12
Miscellaneous	0.07
Driver's wages	5.44
Depreciation	5.00
General repairs	1.07
Running repairs	1.19
Total	27.15

The North of Spain Railways have had, since 1925, two 9-t. (8.9 Engl. tons) locotractors with 4-cylinder, 50-H. P. engines which can haul 200 tons at 45 km. (28 miles) hour on the level. They are of the same length as an ordinary wagon and can turn on turntables; they are provided with capstans for turning themselves or other wagons.

Transmission is by chain to the rear axle, so that only the adhesive weight on this axle is available, but tractors which will be ordered in the future will drive both axles.

The locotractors are fitted with sandboxes.

They have four speeds in each direction and may attain 15 to 20 km. (9.3 to 12.4 miles) per hour.

They are used in stations of moderate size, either to replace shunting engines in stations where these can hardly be justified but where horses cannot cover the work or to replace horses.

They are also used in certain sections of large stations.

They can handle cuts of a few wagons, either 6 to 8 loaded or 10 to 15 empty.

They have the advantage of being always ready for use and be able to go where locomotives cannot pass by using the wagon turntables.

They are generally used for hauling.

They are driven alternately for 8 hours by a trained mechanic and by an assistant. The mechanic is responsible for maintenance and small repairs which he carries out with the aid of his assistant. Heavy repairs are effected by staff under headquarters at Madrid.

The Company states that it is satisfied with the results obtained since 1926 and proposes to purchase three additional tractors.

The cost of fuel, etc., is calculated at 2.5 pesetas per hour, the cost of repairs 1 200 pesetas per year, the cost of maintenance 0.45 peseta per hour in service, and wages cost 1.1 pesetas.

The first cost is 40 000 pesetas.

B.— Steam locotractors.

The four steam locotractors used by the French Nord Company (figs. 18 and 19) can haul 120 tons on the level. They can be used either as tractors, or as capstans, for shunting by means of turntables. They are driven by one man, a shunting driver. Two hours are necessary to raise steam. They are fitted with hand brake and steam brake.

They have been used for about 40 years.

The cost of an hour's shunting is about 15.25 fr., of which fuel, lubrication, water and lighting cost 3.90 fr., maintenance 2.60 fr. and wages (one driver) 8.75 fr.

C.— Other locotractors.

The Nord Company propose to test electric battery tractors and producer gas tractors using wood charcoal. The French State Railways have tried fitting a wood charcoal gas producer to one of their internal combustion tractors, but

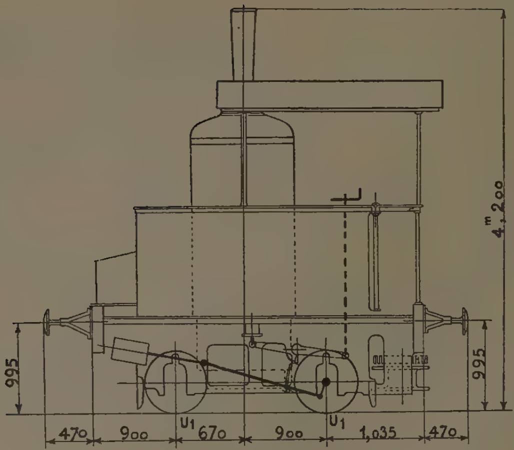

Fig. 18. — French Nord locotractor.

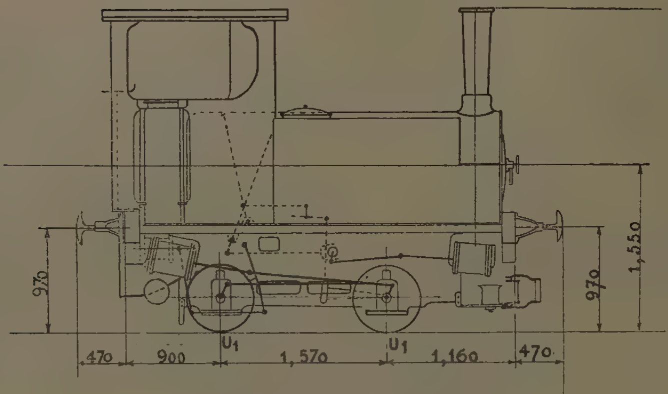

Fig. 19. — French Nord locotractor.

the decrease in the power of the engine caused this to be abandoned. The trial will be resumed with a specially designed engine.

The Italian State Railways are carrying out tests with 40 to 60-H. P. locotractors using fluid naphtha (a fuel costing one sixth or one seventh the price of petrol).

Tractors on road wheels.

Tractors on road wheels have been used since 1922 by the Paris, Lyons & Mediterranean, and since 1925 by the French Est; the North of Spain Railways employ one at the Port of Santander.

The « Bauche » tractor in use on the

two French railways is of narrow width and runs between the rails; it consists of a combined engine and gear box, the casing being of cast steel and serving as a frame.

The lower part of the crank case carries the leading axle and the gear box is supported by the two hind wheels.

The engine has 4 monobloc cylinders of 75 mm. (2 15/16 inches) bore × 125 mm. (5 inches) stroke, developing 18 H. P. at 1 400 revolutions per minute. Its speed is limited to 1 400 revolutions per minute by a centrifugal governor. Cooling is by finned tube radiator with fan and circulating pump. Splash lubrication is used, although the outer bearings of the crank shaft and connecting rods are lubricated by a pump.

A cone clutch lined with ferodo is placed between the engine and the gear box, the latter having two speeds forward of 3.1 km. and 5 km. (1.9 and 3.1 miles) per hour, and a reverse speed of 3.1 km. (1.9 miles).

The wheels are fitted with rubber tyres and the carrying and steering leading wheels are carried on stub axles, steering being controlled by an irreversible rack steering gear.

The two back wheels which drive are not provided with a differential.

The rear part of the tractors is provided with a platform carrying the driver's seat and foot controls. It is fitted with a hand brake and draw gear with springs and shock absorbers. It is 1 m. (3 ft. 3 3/8 in.) in width and 2.60 m. (8 ft. 6 3/8 in.) long. The tractive effort is 1 800 kgr. (3 960 lb.) on the lowest speed.

The Bauche tractor hauls wagons by means of a cable 8 m. (26 ft. 3 in.) long fitted with a special hook. It may also propel the wagons by means of a special buffer consisting of a cross member fixed at the front of the engine.

It is always ready for use provided it is supplied with fuel and lubricant.

The tractor is used in sorting sidings as follows :

a) between periods of shunting to go along the sidings and close up any wagons as may be required;

b) during shunting in going from one track to another where it is required: it does not cross the rails except under the protection of a man provided with a scotch block to stop any wagon which may approach. Crossings are, however, as a rule not carried out except when it is known that no wagons will be sent along the track in question, the man in charge who controls the movement of the tractor being provided beforehand with information as to the numbers of sidings on to which wagons will be shunted.

The tractor is able to deal with *10 to 15 tracks* without any assistance from a shunting engine; the opinion of the French Est Railway is that this number may be increased when more experience has been gained with the use of this method and when crossings made of old sleepers have been provided for crossing the tracks.

The French Est Company points out that the following objects may be gained by this method:

1. To save, in some cases, the use of a special engine for closing up wagons in cases where such an engine is necessarry.

2. To save the use of one shunting engine while dealing with the same number of wagons.

If, in practice, two shunting engines are used, each of these, after disposing

of the wagons, run down the incline and closes the wagons on a certain number of tracks (3, 4 or 5 according to circumstances) and then returns to the arrival sidings to propel another rake of wagons over the hump. When this engine is clear of the incline, the second engine, which is in readiness with its wagons, commences to propel these over the hump. This method of working sometimes causes a delay of 20 to 25 minutes.

3. To appreciably increase the output of the sorting sidings by ensuring continuous operation.

With present day methods, the maximum output may be obtained by using two engines for propelling wagons over the hump, with an additional engine for closing wagons in the sidings. However, as mentioned above, this arrangement does not allow continuous working, as the latter engine can only operate between the shunts.

This is not the case with the tractors, and the French Est Company estimates that the latter allow them to obtain, among other economies, continuous operation, thus increasing the output of the sorting sidings and appreciably postponing the time when fresh accommodation would be required to deal with increasing traffic. It would obviate the necessity for shunting in other sidings to relieve the work in the sorting sidings, which is very inconvenient. It would, at the same time, avoid the equally costly results from choked sorting sidings, holding up of rolling stock and delay in handling goods.

The use of the Bauche inter-rail tractors necessitates the provision of tracks and crossings in the yards where the tractors are used. The tracks can be inexpensively made by old sleepers covered with ballast, and should be kept in good order.

Specially trained drivers are employed who have to undergo a theoretical and practical examination.

One or two men with the necessary technical skill are required for lubrication and running repairs.

In order to avoid any interruption through the tractors being out of service and to ensure that these are kept in good repair, each yard is given a number of spare tractors equal to the number in regular use.

The tractors are housed in special sheds when they are not in service, particulary during cold weather.

A small workshop with a stock of the more important spare parts, petrol reservoir, stage for cleaning and ramp for loading up on the wagons has been provided to facilitate the maintenance and re-fuelling of these tractors.

Before using the Bauche tractors with rubber tyres, the French Est Railway had used tractors with caterpillar tracks and tractors with steel wheels with bars on the rims to obtain a grip. The use of caterpillar tracks was abandoned on account of the expense caused by the rapid wear of the caterpillar tracks and of the drive. The use of steel wheels was abandoned in view of the wear of the bars, their lack of adhesion after a short time in service and the rapid destruction of the tracks caused by these wheels.

The Bauche tractors cost about 45 000 fr., the life being taken as 10 years; their hourly consumption is 3.2 litres (0.7 British gallon) of petrol and 0.25 litre (0.055 British gallon) of oil. The expense of the additional out-lay (tracks, workshop, petrol store) is about 200 000 fr. per shunting yard.

The following figures are given by the

French Est Railway for two tractors used simultaneously for two periods of eight years:

Annual capital charges, tractors	32 500 fr.
Annual capital charges, tracks, workshop, etc. . .	20 000 fr.
Fuel and maintenance of tractors	160 000 fr.
Maintenance of tracks, etc. .	25 000 fr.
Wages	180 000 fr.
Total	407 500 fr.

The Paris, Lyons & Mediterranean uses a Bauche tractor for placing or handling isolated wagons; they have also three Latil tractors which run on a paved track and which may be used in cases where a shunting engine or locotractor cannot be used.

This tractor has 4-wheel drive, steering being by the two front wheels. The wheel base is 2.10 m. (6 ft. 10 21/32 in.), the width 1.70 m. (5 ft. 7 in.) and the total space occupied 4.70 × 2.08 × 1.80 m. (15 ft. 5 in. × 6 ft. 10 in. × 5ft. 11 in.).

The engine, with 4 monobloc cylinders, develops 35 H. P. at 1 200 revolutions per minute; it is fitted with a centrifugal governor. Cooling is by thermo-syphon with radiator and fan at the rear. There are 5 speeds for forward running, viz., 3, 5, 8, 15 and 25 km. (1.8, 3.1, 5, 9.3 and 15.5 miles) per hour and one speed (4 km. = 2.5 miles per hour) in reverse. Above 15 km. (9.3 miles) per hour this drive is direct. The steering gear is of the screw and nut type. Rubber tyres are used, one on each of the leading wheels and two on each of the rear wheels, a foot brake operating on the transmission brakes of 4 wheels; a hand brake acts on the two rear wheels.

The reservoir has a capacity of 85 litres (18.7 British gallons).

The tractor weighs 3 500 kgr. (7 700 lb.) and can be turned in a radius of 6.50 m. (21 ft. 4 in.).

The differential can be locked to increase the adhesion when, owing to the nature of the ground, one of the wheels slips.

Wagons may be propelled or hauled; a wooden cross beam fixed at each end of the frame acts as a buffer; a draw hook is fixed at either end, the rear hook being fitted with a spring.

A platform with padded seat for the driver is provided at the front, while a hood at the back fitted with a large opening allows a clear view to be obtained to the rear.

Acetylene lamps are provided.

The cost of the Latil tractors was 48 000 fr. in 1921.

The cost per hour of shunting for the Latil and Bauche tractors is given by the Paris, Lyons & Mediterranean as follows:

	Latil tractor. Francs	Bauche. tractor. Francs
Petrol	6.05	4.10
Oil	1.55	1.60
Miscellaneous	0.50	0.51
Wages and maintenance	5.44	5.44
Repairs and renewals .	4.50	4.50
Depreciation	3.00	3.00
	21.00	19.15

The Paris, Lyons & Mediterranean Company also employs three 40-H. P. tractors on their Algerian lines; they can haul 20 loaded wagons or 30 empty wagons on straight level track; they are used for shunting at the Port of Algiers; the wagons for the port are placed on a line accessible to the tractor which takes these in small consignments and distributes them

as required for loading, the reverse operation being carried out on the return trip. The tractor also places wagons which, having been unloaded at one part of the docks, have to be re-loaded at another part. Wagons are generally handled by haulage, but in some cases are propelled or hauled by means of a capstan which is fitted to the tractor; this capstan can also be used for turning wagons on turntables.

Owing to the low speed at which the tractor runs, this work can be carried out safely, although no brakes are used except those with which the wagons are fitted.

No information is given as to any damage done to the tracks; all the lines in the docks are, however, fitted with check rails and set in paving stones.

In addition to the man in charge, the use of a tractor necessitates a driver, coupler and pilot; the latter is necessary on account of the regulations governing shunting in docks.

The tractors have been used in Algeria for 3 years and their use will be extended, being much more flexible than that of shunting engines. Wagons can be placed as required by traders much more quickly and cheaply than with locomotives, as the tractor can run easily between the road vehicles and stacks of goods and is thus less liable to be blocked in.

Their petrol consumption is 9 litres (2 British gallons) per hour. The total cost of the tractors was only 100 000 fr. and the shed in which they are kept cost 10 000 fr., including the pit.

The Paris-Orleans uses a Fordson tractor for shunting wagons at Nantes-Maritime station. The experiment has not proved economical, serious drawbacks having appeared, and it has been abandoned.

On the North of Spain a Fordson tractor is used by a contractor to replace horses at the Port of Santander to take wagons from the station to the docks.

The Belgian National Railway Company carried out a test some years back on a Fordson tractor for shunting wagons; this tractor, running between unpaved lines, caused damage to the track and the test has been abandoned.

The Belgian National Railway Company have decided to test the Bauche tractor in a marshalling siding.

Capstans.

The Est uses electric capstans with drums of either one or two diameters.

In the capstans which have drums of two diameters, the 1st size which is 180 mm. (7 3/32 inches) diameter, produces a force of 2 000 kgr. (4 440 lb.) when starting and a normal pull of 660 kgr. (1 450 lb.) at a speed of 0.55 m. (1 ft. 9 11/16 inches) per second. The second drum, which is 300 mm. (11 13/16 in.) diameter produces a starting force of 1 200 kgr. (2 640 lb.) or a force of 400 kgr. (880 lb.) at a speed of 0.95 m. (3 ft. 3 1/8 in.) per second.

In the capstans which have one diameter of drum only this is 300 mm. (11 13/16 inches) and produces the same forces as the second drum of the two diameter capstans.

The power of the electric motors is 8 kw.

The capstans with one drum cost about 10 000 fr., while the others cost about 11 000 fr., excluding the electric power lines, the cost of which ranges from 4 000 to 6 000 fr. per capstan according to circumstances.

The capstans are as a rule operated by the ordinary station staff and specialists are not required for their use.

These devices are used in some stations for shunting wagons in goods sheds and tranship sidings.

The Paris-Orleans Company has used Hillariet electric capstans since 1904 and their use is being extended wherever possible.

They are made of two types, both being suitable for an alternating current of 500 volts.

One type produces forces of 1 200 and 2 000 kgr. (2 640 and 4 400 lb.) on drums of 300 mm. (11 13/16 in.) and 180 mm. (7 3/32 in.) respectively. The speed at half the maximum pull is 0.70 m. (2 ft. 3 1/2 in.) per second. The speed when running free is 1.40 m. (4 ft. 7 in.) per second.

The other type produces a pull of 2 400 kgr. (5 280 lb.). The speed at half maximum pull is 0.37 m. (1 ft. 2 9/16 in.) per second, and the speed when running light is 0.73 m. (2 ft. 4 3/4 in.).

The ropes are as a rule 100 m. (328 ft.) long.

The distance between the drum and the outer edge of the nearest rail should be about 1.50 m. (4 ft. 11 in.) so as to avoid danger to the staff and not give too indirect a haul.

For capstans which only make 4 or 5 shunts per day, a weekly inspection is sufficient. If they are in continual use, lubrication and inspection of the electrical parts should be carred out daily.

The ropes are of hemp and manila, or mixed with a steel wire core. The latter are liable to injure the operators by the steel wires breaking and coming through the hemp. It is very important that the rope should be flexible. The Paris-Orleans uses 4 strand ropes, each strand being made up of a large number of yarns, and does not use 3-strand ropes which are less flexible and wear more rapidly. The ropes are from 25 to 35 mm. (1 inch to 1 3/8 inch) in diameter.

As regards the guide pulleys, these are placed 1.20 m. (3 ft. 11 9/32 in.) from the outer edge of the nearest rail.

The capstans are used for placing and removing wagons from goods sheds by means of turntables, for serving certain sidings which are only accessible by turntable and for hauling empty passenger stock into platforms.

They are worked by two men, a shunter and his assistant, the former attaches or detaches the cables from the wagons, while the latter operates the capstan.

The following figures are given by the Paris-Orleans for the use of capstans, and the results are very good.

The cost of a capstan, including the cost of installation, is 17 700 fr.

The wages of the two men who operate it are 30 115 fr., but they operate as many as say 5 capstans according to circumstances.

We have therefore then :

Annual expenditure:

	Francs
Depreciation	2 655
Electricity 0.65 $\times$ 1 000 kw. . . .	650
Cost of cables, average	2 000
Total:	6 190
Wages $\frac{30\ 105}{5}$ =	6 023
Total:	12 213

35 fr. per 8-hour day.

The French Nord has electric capstans with guide pulleys at 32 stations; the force produced being 400, 900 and 1 100 kgr. (880, 1 980 and 2 420 lb.) according to type; it is possible to haul 50 tons at 1.5 m. (4 ft. 11 in.) per second. The

ropes are 100 m. (328 feet) long, which gives the capstan a range of action of about 75 m. (246 feet).

The Paris, Lyons & Mediterranean also employs electric capstans with hemp ropes.

Electric capstans are also in service on the Belgian National Railway Company at the Antwerp Docks for placing wagons alongside ships in lieu of animal haulage.

Traversers.

The French Est Railway uses electric traversers.

a) having a table 10.50 m. (34 ft. 5 in.) long capable of dealing with wagons having a wheel base of 9.67 m. (31 ft. 9 in.) and a weight of 46 t. (45.3 Engl. tons); they can also haul 600 tons.

b) having a table 9.80 m. (32 ft. 2 in.) long for 22-t. (21.6 Engl. tons) wagons, and capable of hauling 160 tons for one type and 100 tons for another type.

The first cost of the 10.50-m. traverser is about 150 000 fr.; the working costs, including depreciation, are about 25 000 fr. per annum, excluding labour, which is supplied by the ordinary station staff.

The traversers are used for shunting at certain stations and tranship sidings.

The Paris-Orleans also uses traversers for marshalling and sorting fast freight trains and for moving wagons along fast goods platforms. They can deal with a maximum load of 50 tons. As a rule they take alternating current at 500 volts.

The staff required is as follows:

1 traverser man (labourer).
1 shunter in charge.
1 cable man (labourer).

They have been used since 1904 at all places where they can be employed with advantage.

They are very suitable for shunting fast freight traffic in dead-end stations and cost 30 000 fr.; it is stated that a considerable amount of current is used for traversers in continual use, being 9 000 kw. per year.

The French Nord uses electric traversers at two stations for serving goods sheds, 3 at Lille St. Sauveur and one at Amiens. They have 5 traversers in use at La Chapelle-Charbons for handling coal traffic, these being operated by means of a capstan, the sheds and sidings being difficult to lay-out with points and crossings.

The Paris, Lyons & Mediterranean also uses traversers running on transverse tracks and hauled by electric tractors or steam tractors.

The North of Spain Railways state that they employ electric traversers and tractors with capstans.

The Belgian National Railway Company uses traversers operated by electric capstans for shunting at Antwerp Docks on lines which are not accessible by points and crossings.

Miscellaneous.

1. The Paris, Lyons & Mediterranean states that it has tested a trolley fitted with a hand winch driving a wheel running on the rail. No further particulars are given.

2. The use of special pinch bars is mentioned by the Paris, Lyons & Mediterranean and the Belgian National Railway Company for small movements of single wagons.

3. Horses are still employed in certain stations on the North of Spain, Paris, Lyons & Mediterranean, French State, Paris-Orleans and French Est. The tendency is to replace them by tractors or capstans. The horses are hired by the

day or hour; the price varies in France between 30 and 60 fr. per day for a horse and driver.

* * *

To summarise, the special methods of haulage which may be effectively used for shunting in stations of minor importance and for certain shunting operations in large stations are as follows, as far as concerns the administrations dealt with :

1.— Locotractors running on the rails, frequently fitted with capstans, and driven by one man.

Internal combustion locotractors are in use on the North of Spain, on the French Est, Paris, Lyons & Mediterranean, French State Railways, Paris-Orleans and French Nord.

Steam locotractors have been used for as long as 40 years by the French Nord.

The most up-to-date rail locotractors have internal combustion engines working on petrol. There is a tendecy to substitute cheaper fuels, or those which can be produced in the country, for petrol, such as gas produced from wood charcoal. The use of storage battery locotractors has also been considered with the same object.

The locotractors replace small shunting engines or animal haulage. They have the advantage that they can go to places were locomotives cannot be worked owing to the possibility of their being turned on wagon turntables.

In one case where they have been used in place of locomotives in order to avoid the effects of smoke and steam, their use has resulted in an economy of 40 %.

2.— Internal combustion tractors running on rubber tyres. These are used on the Est and Paris, Lyons & Mediterranean in France and also on the North of Spain.

They replace either locomotives or horses under certain conditions. The use of a tractor sufficiently narrow to run between the rail tracks in order to close up wagons which have been sorted out at gravity sidings is of particular interest.

3.— Electric capstans.

4.— Electric traversers or traversers operated by an electric or steam tractor.

Capstans and traversers are mainly useful for placing wagons in sidings which are not accessible by means of points.

The use of horses for shunting tends to disappear.

[656 .1 & 656 .2]

REPORT No. 5

(Germany)

ON THE QUESTION OF COMPETITION OF ROAD TRANSPORT (SUBJECT XIII FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION) (1) (2),

By Dr. ZIETZSCHMANN,

Reichsbahndirektor, Member of the Headquarters Administration of the Deutsche Reichsbahn Gesellschaft (German State Railway Company).

CONTENTS

(1) This question runs as follows: « Competition of road transport. Effect of road competition on goods and passenger traffic and the best methods of meeting such competition, both as regards the main lines and the branches. »

(2) Translated from the German.

I. — Extent of motor vehicle traffic in Germany.

In Germany, as in other countries, motor vehicle traffic has developed to such an extent as to have an acute effect, both on the railways and on German domestic economy.

Statistics are wanting, in Germany as in all other countries, which include the whole of the working results of the motor vehicle traffic. Accurate figures concerning passenger and tonne-kilometre statistics, are only available for a few undertakings, such as the Omnibus department of the German Post Office and the Motor traffic branch of the Deutsche Reichsbahn Gesellschaft. On the other hand, there exists a comprehensive official statement, giving the number of power driven vehicles. In appendices 1 to 3 the correct totals for 1914 and for the years 1921—1929 are tabulated.

The figures therein given show that between the years 1914 and 1929, the number of motor vehicles has increased thirteen times.

The statistics also give important information as regards development which will be gone into later.

More than 80 % of the total number of vehicles come under the head of passenger carrying vehicles. In this class, the motor bicycle has increased enormously in numbers during the last few years and holds the first place as far as numbers go in the total of the passenger carrying vehicles, next come the 2—6 seater motor cars and after them the motor bus.

Apart from the omnibuses, only about 2 1/2 % of the passenger carrying vehicles are employed in commercially managed passenger traffic. Thus, by far the greater number are employed on non-commercially operated traffic.

The numbers of the motor lorries have increased in almost equal ratio to those of passenger vehicles. The greatest increase comes under the head of the light lorry with a carrying capacity of 2 tons.

This type stands well at the top of the list of weight carrying vehicles.

Of late years the number of motor tractors in service has largely increased, as have also the numbers of motor lorries of the heavy type, with a capacity of over 5 tons, while the medium type of lorry with a weight capacity of 4 tons, which formerly held a prominent position, has increased in numbers much more slowly and has even shown a falling off in numbers.

The majority of motor lorries are not the property of transport undertakings but belong to industrial and commercial concerns who themselves operate as carriers.

All the motor vehicles which are wholly or in part engaged in local traffic are included in the statistical returns. It is not stated in the statistics how many vehicles of each kind are engaged in this form of traffic, or in cross country traffic. Only for the motor omnibuses can it be said that 3/4 of them are operated on cross country work.

It is only possible to give an approximate estimate of the total *passenger and tonne-kilometres run by the motor vehicles* in cross country service.

It is assumed that during the year 1928 the total passenger-kilometres run amounted to about 14 milliards (8 700 000 000 passenger-miles);

The total tonne-kilometres run were about 4 milliards (2 450 000 000 Engl. ton-miles). About half this mileage has to be allocated to cross country service.

As against these figures the Reichsbahn ran 47.65 millards of passenger-kilometres and 66.5 milliards of goods ton-kilometres (29 600 000 000 passenger-miles and 40 670 000 000 English ton-miles respectively).

Of the Reichsbahn figures, only a small proportion is due to local traffic.

When it is realized that the figures for motor traffic are not very reliable, it is certain that motor vehicle traffic, in spite of its great increase, is to-day and will be for some time of less magnitude than that of the railways and also of less importance for the public.

II. — The various kinds of motor vehicle traffic.

1. — Traffic carried by the smaller passenger vehicle.

There is no doubt that the light 2—6 seater motor car has brought upon the roads an increasing amount of entirely new traffic.

This is true, not only for the purely local sphere in which the increase of traffic in the streets is clearly visible to every one, but also for long distance traffic, even in those connections where railway facilities already exist.

The reasons for this are to be found in the well known advantages which the motor vehicle can offer.

These are the independence, the possibility of very much quicker travel over short and medium distances, the special charm of travelling through beautiful surroundings and finally, when the owner of the car drives it himself, the sport and amusement. Added to this is the interest which every car owner has, in getting the greatest possible use out of his machine, and it is these circumstances which taken as a whole are often the reason that the car is used *in preference* to the railway.

It is hard to say with certainty, that any particular journey made by car has deprived the railway of traffic or to say that in the absence of a car the journey would not have been undertaken, but it is certain, that of the journeys made, a considerable fraction of those made for pleasure or business purposes, represent a loss of traffic to the railways.

This loss is the more serious for the railways in that it has to do with the better class passenger, who mostly travels by rail at the normal rate, while a considerable number are carried in the upper classes. The passenger traffic carried at reduced rates, and especially the large workman and employee traffic, remains almost entirely in the hands of the railways.

As reduced fare concessions and adjustments of rates for the individual classes in the normal tarif are dependent on the possession of the more valuable traffic, so must the loss of this traffic to the motor vehicle, of necessity, lead to a drastic levelling down of fares.

This result had already commenced to take effect with the rate alterations undertaken in 1928, in the normal tarif of the German Railways.

The fares of the new « Wooden Class » were raised from 3.3 pf. to 3.7 pf. per passenger-kilometre (5.3 to 6.0 pf. per passenger mile), as compared with the earlier fares of the fourth class. As against this, the fares of the second class were lowered from their former level of 7.5 pf. to 5.6 pf. (12 to 9 pf. per passenger-mile). When concurrently with this recent refixing of rates, other circumstances, such as the impoverishment of Germany, have caused the movement of many passengers from the upper to

the lower classes, the motor vehicle traffic is also exerting considerable influence.

The result of the competition of the motor vehicle for passenger traffic will be an inevitable increase in the cost of rail travel, especially for the heavy traffic of the great mass of the public.

2. — Motor omnibus traffic.

In the case of the motor omnibus it is necessary to differentiate between line traffic, that is to say traffic following a regular route, and excursion traffic. In accordance with the existing regulations, excursion traffic is free from all official control, while the operation of traffic lines is under the control of local Authorities. The license to operate is given to the undertaker in person. This license in general not only lays down the route to be followed, but also the stopping places, and fixes also the time table and the fares. The lines worked by the German Railways including the Reichsbahn work under license obligations especially when it is a case of traffic carried directly parallel to the rail, which might possibly replace train services.

The German Postal Service alone is free from license obligation, in consideration of its former horse drawn, country wide connections, and in appreciation of its duty to deliver postal matter over the whole country, even where there is no rail provision.

Any person, in common with the Railway Administration, whose interests may be affected, has the right to enter a protest against the decision of the licensing Authority, concerning the starting or abandonment of a service, and this protest is dealt with by the Central Authority of the State concerned.

The experience which the railways have had with this regulation, which has remained practically unchanged since 1919, has not been altogether satisfactory. The disadvantageous reaction which competitive motor traffic has on the railway traffic is not always sufficiently considered by the Licensing Authorities. The necessity for the setting up of a service, which in accordance with law must as a rule be agreed to by these Authorities, will usually be conceded, when local opinion supports the demand for the service.

A thorough investigation is however only made, as to the value of the service to the common good, when it is a question of the selection from a number of alternative routes, of one, which if it is adopted, must condemn the rest. As against this, the value of a motor service, as compared with that of a railway service, adversely affected by its competition, is seldom investigated.

The prescriptive right of a railway to motor services which directly trench upon its traffic spheres and which may cause competition, has so far not been recognised in Germany. Only one State Government has ruled that in the case of a motor service whose competitive character is admitted, the railway affected shall have the option of undertaking the proposed service. The practical operation of this ruling is however, up to date, negligeable.

As a rule the competitive character of a service will only be admitted so long as it directly connects points already connected directly by rail, when the motor route is of the same approximate length as the railway section concerned and when the motor service transcends the dimensions of local service.

These narrow limits are not in effect just, as the railways are responsible for

the maintenance of local traffic, — on the Deutsche Reichsbahn the average journey length is only 23.7 km. (14.7 miles) — and they have to bear carefully in mind that many of the smaller and medium sized stations, can only be kept open for goods traffic as long as the passenger traffic of the surrounding places is worked by them.

Taken as a whole the concession regulations have served rather to prevent the railways from setting up their own services, than to protect them from injurious competition.

The total length of the motor omnibus service network in Germany is to day approximately 55 to 60 000 km. (34 to 37 000 miles) in length.

It is of about the same length as the rail network of all the German railways put together, namely 57 000 km. (35 500 miles).

Far more than half the bus network is operated by the German Postal Department. This department had in 1928 a network of about 36 700 km. (22 800 miles) under its management.

In spite of this the traffic carried by the omnibus services is very much less than that handled by the railways. For the year 1928 this was estimated at rather more than 2 milliards of passenger kilometres (1 245 000 000 passenger-miles) or only approximately 4 % of the rail borne traffic of the Reichsbahn.

The average length of the individual bus routes on long distance traffic is at present about 18.5 km. (11.5 miles). In recent years however the number of services running over longer distances is being steadily increased. There are now a large number of services with lengths of over 100 km. (62 miles).

The long distance lines are mostly so called express services, which only serve terminals or at most a small number of intermediate stopping places.

Motor bus fares vary between 5 and 10 pf. per passenger-kilometre (8 and 16 pf. per mile) or an average of 8 pf. (12 pf. per mile), therefore altogether higher than the fares for the « Wooden Classes » (1) of railway traffic and even considerably higher than those of the « Upholstered Classes » (2).

The dearness of the bus fares is the reason that, when the motor bus comes into competition with the railways it attracts mostly only the more valuable traffic. The heavy business traffic remains almost entirely in the hands of the railways, even in respect of places which do not lie directly on the railway and for which the motor omnibus undoubtedly provides a more comfortable mode of travel.

It must not be forgotten that the motor bus has provided a welcome and economical form of transport for places at a distance from the rail, and for poorly served districts, and owing to the opening up of these places and properties, has brought the railways a certain amount of feeder traffic. A similar and very useful omnibus traffic has been developed over large areas in Germany solely by the German Postal Department, which uses motor traffic in the way of an extension of the railway, as an aid to their postal delivery service.

There are nevertheless many routes among the postal motor services which cause considerable competition with the railways.

They greatly exceed the competitive services run by the other motor transport undertakings, i. e. transport companies and private contractors.

(1) 3rd and 4th classes.
(2) 1st and 2nd classes.

The reasons for this are clear. Motor transport businesses have as a rule no interest leading them to consider the traffic on the railways. The basic objective always before them is to make their transport businesses as profitable as possible. As a result of the high cost of motor bus working which, depending on the size of the vehicle and the nature of the route, lies between 0.55 and 1.40 Rm. per bus-kilometre (0.88 and 2.25 Rm. per mile), services can only be run at the fares given above, where a proportionate density of traffic ensures a good average patronage of the service. Owing to the density of the German railway network, which is so laid out that no place lies more than 18 km. (11 miles) from the nearest railway station, all districts with a sufficiently dense traffic are already served by the railways. An existing railway traffic naturally makes the choice of a location in which a profitable bus service can be set up, very much easier.

In conclusion it must be stated that the development, up to date, of the motor bus traffic in Germany, has tended more in the direction of producing an injurious division of traffic, rather than in providing a useful addition to the existing railway network.

The economic result of the motor bus in respect of long distance traffic is at present very doubtful.

3. — Motor lorry traffic.

a) The motor lorry in local service.

As in the case of passenger traffic, the use of the motor lorry for goods traffic has led to a considerable increase in purely local traffic.

But while in the case of passenger traffic, the increase has only affected the railways in the environs of a few big cities, where the railways themselves have undertaken local services, it is otherwise in the matter of goods service.

The development of the motor lorry has still further increased the subdivision of incoming and outgoing consignments at goods stations, because it has not only resulted in the use of more vehicles, but also in an increase of the number of vehicle owners. This has been followed by an increase in the cost of loading and dispatch for the railways, at least at the larger stations, because the large number of customers who fetch their goods themselves and either dispatch themselves or authorize agents to do so for them, makes the business troublesome, time wasting and impossible of supervision.

This subdivision has also adversely influenced the working costs of the carriers, owing to the distribution of a not greatly increased amount of traffic between a much greater number of vehicles and carriers. This has increased the working cost considerably as compared with former times.

It follows then that the higher cost of labour has increased the tendency of those seeking traffic to avoid so much running backwards and forwards, while the carriers are, on account of the small amount work done by their vehicles in local service, driven to activity in long distance service.

In this way the expansion of the motor lorry in local service is affecting the long distance motor lorry development.

b) The motor lorry in long distance service.

It is necessary to distinguish between the motor lorry business which carries goods for third parties, and the so called

works traffic, which is operated by commercial and industrial undertakings with their own lorries, for the purposes of their own businesses such as carriage of raw material, transport between detached establishments or delivery of goods to customers.

It is only commercial traffic, and that only when it is run on fixed routes, that is controlled by official license. This license imposes the same conditions as for the bus services. In this matter the railways are subject to the same extent to the obligations imposed on the private contractor by the licensing Authorities. The before mentioned exceptional position of the Post Office refers to passenger traffic only.

The Licensing Authority, in the case of goods services fixes the routes and occasionally the stopping places, but only in exceptional circumstances the schedule and rates. Legislation in so far as it affects the concessions for goods services has had little practical result. There are very few goods services running between fixed points, over regular routes and to fixed schedules.

The reason for this is to be found in the fact, which sooner or later has to be considered, that delivery cost is in great measure the determining factor in cross country traffic. This cost can only be kept low if the vehicle can be supplied on its journeys with favourable loads on both out and home trips. This result can only be obtained as a rule by a motor traffic service which retains a certain flexibility and which arranges that the service shall be proportioned to the supply of traffic as closely as possible.

In accordance with the working instructions for the motor service regulations of the Motor service law, only such service shall be considered as a line when its frequency and regularity are such that the public can depend on it. The competent Authorities have so far made little use of the opportunity to influence the increasing cross country traffic in a proper direction, and to make injurious traffic competition with the railways impossible.

By far the greatest mass of the motor lorry traffic and in particular, both the commercial and works traffic, is worked over short distances of up to 50 km. (31 miles). This short distance traffic develops principally in the neighbourhood of the large cities and within the thickly populated business areas. Nevertheless the motor lorry is always to be found on short haul traffic, in poor traffic districts, and in connection with towns at a distance from the rail.

Within local zones, industrial traffic considerably exceeds the other descriptions of traffic. By far the most popular type of lorry for this traffic is one with a carrying capacity of up to 2 tons.

In long distance traffic, the motor lorry is to-day operated over distances up to 500 km. (310 miles). It is however in the zone between 100 and 200 km. (62 and 124 miles) that the traffic is heaviest. In long distance traffic it is the commercial traffic which preponderates, and that increasingly as the distance increases. It is clear that as the distance increases, it is more necessary to put transport on a broader basis, that is to say, to combine the goods of a number of consignors and consignees, so that a better load may be secured for the vehicle both on the out and on the home journeys.

This class of transport is in consequence carried on largely by carrying contractors, not so much with their own lorries as by subcontract with small owners, who often run their business with the

help of relations and are not therefore hampered by legal restrictions as to hours of work, and who, because they do not work out their costs properly, often carry cheaper than the large companies.

For long distance traffic, the type of lorry most in favour is one with a capacity of 4 tons and over. In this branch of traffic also, traffic is often carried by subcontractors, and very often in lorries which are loaded beyond the limits allowed by law.

With increase of distance, the advantage of having the vehicle fully loaded also increases, and it is evident that it is only possible to work between large centres able to provide full loads in both directions. While, in local traffic, the motor lorry comes in connection with places which are either not served at all by the railway, or are only served by branch lines, and has on that account and because of the great advantages it gives, developed a new traffic of considerable proportions, there is with few exceptions, little motor lorry traffic between places already connected by main lines of railway, which should not be looked upon as in competition with the railway.

c) The effect of motor lorry working on traffic and economy.

In comparison with the railway, the motor lorry offers the possibility of very convenient dispatch in the case of occasional traffic. This is so chiefly on account of the great independence of this means of transport on any particular route. Unlike the railway, the motor lorry is not tied down to any fixed route, but can be employed on almost any cross country connecting route, and it is possible to effect a door to door delivery without having to tranship the goods or to carry them to and from intermediate depots. The railways can, only offer similar service where rail connections exist.

The freedom of movement relieves the motor lorry of the necessity of working to a fixed schedule or to fixed receiving and delivery times. It therefore gives to those interested in transport over short and medium distances, a more convenient and quicker service.

Door to door service may also cheapen carriage. A saving is possible in the cost of carriage to and from intermediate receiving and delivery points. The shorter the intermediate length, the more the local cartage charges mount up. In the case of the railways when the distance is less than 50 km. (31 miles) these charges come to more than half the total cost. The saving in cost of carrying to and from receiving and dispatching points is valuable to those managing motor lorry traffic, but it must be admitted that this advantage on long distance traffic, at least as concerns industrial traffic, is generally only of practical value for consignments of over one ton. Consignments of less than this weight are in general in long distance traffic debited with local cartage charges.

A further cheapening is in some cases possible with motor transport, because with door to door cartage a smaller expenditure is required for packing, and as a result of the absence of transhipment, the danger of damage to goods is reduced. This advantage is not however always obtained as on occasion the same class of packing is demanded as for railway transport. In conclusion, it may be claimed for the motor lorry as an advantage, especially where the motor vehicle belongs to the suppliers themselves, that it makes for closer relations with the

customers and it can also be used for purposes of advertisement.

Greatly as the above mentioned circumstances have aided in the spread of the motor lorry, they have been decisive in the increase of the motor lorry for local traffic. In long distance traffic, the main cause of the steady increase of the motor is to be found in the fact that those who are operating this traffic by means of the motor lorry, can make considerably cheaper delivery especially for the intermediate trips. This is due to the fact that the costs of the motor lorry working are lower. The amount of the cost per individual tonne-kilometre for motor traffic varies naturally in the same way as it does for railway traffic. It is dependent on the nature of the section of the road, the type of vehicle used, its degree of utilisation, the extent to which it is loaded and finally on the description of freight carried. The actual cost per tonne-kilometre for motor transport over long distances varies at the present time, assuming the vehicles to be run under fairly favourable conditions, without including loading and unloading charges, between the amounts of 8 and 30 pf. (13 and 49 pf. per Engl. ton-mile). The average runs to about 15 pf. (24.5 pf. per Engl. ton-mile). At the present time, owing to existing laws governing motor transport, the conditions are in many respects favourable for low running costs. This is a matter that will be specially dealt with later on.

Against this is to be noted the fact that the cost per tonne-kilometre for Reichsbahn rail borne traffic, including the cost of dispatch and loading services, averages only 4.6 pf. (7.5 pf. per Engl. ton-mile) and this covers all charges which have to be borne at present by the Reichsbahn over and above their actual costs. In the case of dense long distance traffic consisting exclusively of complete wagon loads, which is the type of traffic where road transport appears almost exclusively as a competitor, the costs of the railways are lower still. Properly speaking, in making a comparison of the cost of the two types of transport, one is only justified in taking into account that part of the general cost of the rail traffic which is an increase required to provide the service for the traffic in question, or inversely, the amount that may be saved in the event of such traffic being diverted elsewhere.

If, in spite of this unfavourable comparison in regard to costs the motor lorry can still offer cheaper transport to the user, the reason must lie exclusively in the ruling method of fixing the railway tariffs and in the scale of charges.

Whereas the road transport vehicle is in a position to select goods, customers and traffic conditions which appear most suitable for realising the most favourable economic results, and is free to leave to the railway those goods which do not meet these requirements, the railways are obliged by law to transport goods of all kinds, dispatched by any persons to any destination which can be reached by their system.

The railways, moreover, are compelled to carry out their transport at tariff rates which are the same for everybody and must be published.

The freight rates of the German railways are principally based on the general industrial economic conditions. Goods are classified according to their greater or lesser intrinsic value and also according to whether they are principally to be considered as raw materials, semi-finished or finished products for indus-

trial purposes, the charges vary accordingly.

The freight rates are subject to reductions for longer distances.

The road transport vehicle takes advantage of this system of tariffs by concentrating on short distance traffic and in addition especially in the case of longer distances — restricts itself to those goods which are listed in the highest classes of freight rates by the railways. In this way and in spite of its higher running cost, the road transport vehicle is able to under quote the railway and moreover in some cases with a substantial profit.

The greater the competition of the road transport vehicle becomes and the more it is extended, the more the maintenance of the existing tariff system, which for many decades has formed one of the most important bases of industry in general, is endangered. This development will lead either to an extensive differentiation in the assessment of freight costs by rail for the same classes of goods, according to whether there is competition by road transport or not, or to a marked levelling of the rates, that is by a reduction of the higher tariffs and an increase of the rates for the lower classes of goods. In both cases an increase in the cost of transport of bulk goods and raw materials which are vital to German industry, will ultimately be unavoidable.

In what way this development will take place either as regards industry in general or the railways themselves in particular, can not at the present moment be foreseen. There is, however, serious danger, that it will lead to a substantial increase of the general charges on industry due to freight charges and to the destruction of numerous subsidiary manufacturing and industrial undertakings.

III. — Railway losses resulting from road motor traffic.

There is no doubt that the increasing employment of road transport is causing a continually growing reduction in the income of the railway undertakings and that these reductions have already reached a substantial figure. It is a matter for investigation however to ascertain at what figure in terms of money, the losses on the whole are to be estimated and whether the railways are not benefitting in another direction by an increase of traffic due to road transport concerns acting as feeders.

It is difficult to arrive at an exact estimate of the figures for losses of income by the railway companies, more especially as many other circumstances apart from the development of road transport, affect the development of railway traffic. Among such influences may be reckoned changes in the density of population, with variations in trade conditions, rearrangements in individual branches of industry and alterations in the systems of power and heat supply. The state of railway traffic is also greatly influenced by measures which the railways may adopt within their own sphere as regards the tariffs and the transport of passengers and goods. Further, as has already been stated, reliable statistics regarding the traffic handled by road transport are still wanting. We therefore must depend to a great extent on estimates, in order to arrive at the loss of income to the railways.

The figure which may be assumed for the loss on the whole of the German railways has not yet been definitely deter-

mined. On the other hand the injury suffered by the Reichsbahn as a result of road motor traffic has in the last years been repeatedly subjected to extensive and careful investigations. In carrying these out, various methods were adopted in order to balance up as far as possible, errors which were bound to creep in with one or other of the methods employed. In order to arrive at these estimates calculations were made of the probable total of traffic handled by all types of motor vehicles, local investigations were made as to the type and extent of the road borne transport, investigations were conducted at the goods departments of the railways, at the offices of the transport agencies etc.: with respect to traffic which was originally rail borne and is now road borne and finally statistics of the total traffic handled by the railways. The result of all this for the year 1928 was a follows:

In passenger traffic there was at least a loss of between 140 and 150 million Rm. not including the traffic carried by road transport acting as feeders to the railways; of this amount approximately 30 million Rm. was accounted for by the regular motor bus traffic.

As regards goods traffic, the nett loss for 1928 would appear to have amounted to at least 180 million Rm. The diverted traffic covers only a relatively small portion of the goods carried at the lower tariff rates, moreover such goods refer almost exclusively to the short distance zone.

The goods classified at higher rates for wagon loads, and those for single parcels traffic are affected to a much greater extent. Goods traffic, as a whole, has during the last four years increased by approximately 16 %, where as the increase in goods of the higher classifications has shown an increase of only 5.8 %, this latter traffic has thus only reached the 1914 level.

The single parcels traffic has likewise only suffered serious loss in the short distance zone. On the long distance hauls, the diversion of single parcels traffic to road vehicles is to a great extent equalised by the fact that the road vehicles only took a portion of the goods which were formerly sent by rail in wagon loads and the remainder was carried as single parcels goods by rail because there was not enough to make up complete wagon loads.

In the foregoing figures of loss, all economies which might have been effected by the railways as a result of diversion of traffic have been taken into account. These economies as far as passenger and wagon load traffic are concerned, are unimportant owing to the relatively small extent of the road borne traffic. It is only with the single parcel traffic that certain economies can be effected, and even so these are very limited.

Moreover the total advantage of road borne traffic acting as a feeder to the railways is taken into account in the above mentioned figures. As regards passengers, it is the omnibus traffic alone which comes into consideration. Even in this case the advantage gained is comparatively small; for the year 1928 it could at the very most be estimated at from 5 to 6 million Rm.

Even in goods traffic, the advantage from feeder routes is purely nominal. This arises from the fact that where motor lorries are used for transport going beyond a particular locality, one of their important advantages lies in the fact that delivery can be made without transhipment and without changing the means of

transport on the road. Finally the question has to be gone into as to what extent the road transport business adds indirectly to the goods traffic of the railways by freight arising out of motor vehicle industry, such as fuel etc.

The Deutsche Reichsbahn emphatically rejects the view that such traffic should be considered as an increase due to road borne goods traffic.

This railway is of opinion that this traffic is to a great extent simply the outcome of a change in the incidence of traffic brought about by the alteration in the organization of industry due to the influence of motor transport. The increase in freights due to the development of industries connected with motor vehicle traffic has to be set against a substantial reduction in freights connected with other industries from which capital and labour have been transferred to the new automobile industry — as for instance locomotive and rolling stock factories — such industries have suffered a heavy loss of business resulting from the influences of road borne traffic on the finances of the railways. But even if we reckon the freights coming from the motor vehicle industry and the supplies for running mechanical transport as a gain, the above mentioned comparative reduction of traffic in the higher tariff goods shows how little these freights are in a position to make up for the losses due to traffic taken away from the railways by the motor lorry working on road transport. It will be remembered that by far the greater part of the raw material, semi-finished and completely finished goods, used in the automobile industry and that used for operating mechanical transport, are goods belonging to the above mentioned higher tariff classes.

It is therefore estimated that the total loss which has been suffered by the German State Railways alone for the year 1928 as a result of motor vehicle traffic is not less than 320 million Rm. As against this, it may be noted that the total gross receipts of the Reichsbahn for 1928 were about 5 154 million Rm.

A further increase in the loss of income of from 10—15 % may be expected with certainty during 1929.

IV. — The exceptionally favoured position of the road motor lorry under existing regulations.

It has already been pointed out that the motor lorry is favoured as compared with the railways by the fact that, in so far as it is run for profit, it is not subject to any obligations either to maintain service or to carry goods at a fixed tariff, available for inspection by the public. These are not however the only advantages which motor vehicle transport enjoys from the existing legal position.

The motor lorry has the further advantage that its road is built and maintained by public funds, while the railways have to build an maintain their own road. Total expenditure for road construction and maintenance in Germany for the financial year 1927—1928 amounted to 670 million Rm.; the actual requirements are however materially higher; thus the annual expenditure for the next ten years is put down by experts at from 900 to 1 000 million Rm. Even if it is possible to lower maintenance costs by a thorough reconstruction of the road surfaces, financed by a loan, the annual outlay will be considerably above the amount hitherto spent on the roads. The annual expenditure during the prewar period was only about 150 million Rm. This would now be equivalent to

about 270 million Rm. if the general increase in cost of labour and materials following the war is taken into consideration. The entire difference between the above totals (270 and 900 to 1 000 million Rm.) may be debitable to motor vehicle traffic. In effect the motor lorry makes a quite inadequate contribution towards these costs.

The motor vehicle tax, the only tax which motor vehicle traffic has to bear for the benefit of the road fund, produced the following sums during the last few years:

Year 1926	105 million Rm.
Year 1927	156 million Rm.
Year 1928	181 million Rm.
Year 1929	205 million Rm. (estimated).

It should be noted that in the sums mentioned above for road building and maintenance nothing is included, neither for completely new roads, nor is the smallest sum included to meet interest or amortization on the capital sunk in existing roads.

The motor vehicle is in addition greatly favoured in another direction, namely, as regards the policing of its roadway.

While the railways have to look after the safety of their road for themselves, the charges incidental to the traffic police, which in consequence of the increasing motor traffic, are growing all the time, fall without exception on the general public.

The increased cost of policing the traffic on account of the motor vehicle may be estimated at 25 million Rm. annually for the large towns alone.

Even as regards actual rates and taxes, the motor vehicle is considerably better off. The transport of passengers and goods by rail is subject to the « traffic tax ». This amounts with passenger traffic (graded according to class) to from 11 to 16 % of the cost of the journey while for goods traffic the uniform charge is 7 % on the freight. Only coal transport is free from this tax. In contrast with this, motor vehicle traffic is only subject to a tax when the vehicles are run for business purposes for profit, and even then the tax only amounts to 0.75 % of the turnover.

The entire passenger and goods transport, carried on in privately owned vehicles or vehicles owned by works and factories is tax free.

In view of the fact that, as shown above, by far the greater part of the motor vehicle traffic belongs to the two last mentioned classes, the arrangment amounts to a substantial subsidy for those travellers and consignors who use motor vehicles instead of the railways.

In addition as is well known, the Reichsbahn has to find a considerable proportion of the annual reparation payments due by the German State and this, without counting the traffic tax, amounts to 660 million Rm. per annum.

A further difference is to be noted regarding responsiblity for individuals and goods. In its passenger service, the railway is liable by law for full damages in the event of death or injury of any person, unless it can be proved that the accident occurred by Act of God or was caused by the personal negligence of the party in question. In the case of goods traffic the railway is liable under the severe terms of the Railway Traffic Act, by which it is obliged — apart from certain exceptions — to compensate, without the necessity of negligence being proved, fully for damage or loss of goods, which may take place between the acceptance and delivery of the consignment.

The liability of the motor vehicle owner is on the other hand much less. There is no liability for damage caused by unavoidable circumstances not due to any defect in the vehicle or its parts, or if it is due under certain circumstances to excusable behaviour on the part of the injured or deceased person. The expression « unavoidable circumstance » enjoys in law a much wider interpretation than the expression « Act of God ».

Moreover, the liability is limited to very moderate maximum figures both for causing death or injury to persons and also for damage to inanimate things. There is no legal liability for the safety of persons or things actually carried in the vehicle itself.

The owner of a motor vehicle is only liable to the extent of any special undertaking which he may make with the parties concerned.

All these privileges which the motor vehicle enjoys in respect of liability appear all the more unjustified, inasmuch as the danger of accident, as is shown in the following statistics, is far greater in the case of the motor vehicle than in railway traffic:

By	As °/₀ of all accidents.	Total injured.
Railway 1926	4.5	931
— 1927	4.6	1 014
Motor vehicle 1926	11.5	2 379
— 11 3/4 1927	15.1	3 305

V. — The prevention of competition.

The goal in the prevention of competition by the motor vehicle is not to be reached by preventing by all possible means the growth of motor vehicle traffic in general, but by inducing a proper division of the traffic between the two methods of transport, from the point of view of common good.

Since it is impossible to divide the traffic so long as the railways are subject to such differential treatment in law, as has been shown above, it will first be necessary to abolish the legal privileges which the motor vehicle at present enjoys. The motor vehicle must be debited with full and just proportion of the cost of road construction and maintenance and must also bear a proper share of the cost of traffic police. Further, liability in both types of traffic must be equalized. It is essential that it be arranged that both systems shall for public purposes submit to alterations in the way of equalization. Without such alterations of the law, it would seem altogether impossible to place the two systems of transport on a sound economic and healthy basis.

In addition, the concession laws would have to be extended so as to make them of greater practical importance for goods traffic, so that the whole of the motor lorry traffic and not merely the regular lines should be subject to authorization, at any rate for the long distance cross country traffic.

It is obvious, however that these legal measures alone will not suffice to ensure to the railways in their fight with motor transport, the share of traffic that is their due. To secure this it will be necessary in the first instance that the railways themselves should adopt protective measures.

As regards *passenger traffic*, the most important means for the railways to retain their traffic in face of motor

vehicle competition, are improvement of the railway services by more frequent trains, cutting down the running times and increasing the comfort of the passengers in the trains. The development of excursion and week-end traffic and the extension of society trips will help to retain and extend the business of the railway.

In addition to taking such measures on the railways, motor services run by the railways themselves will serve to avert motor competition threatened from other directions. A motor vehicle service may not only be considered in the way of a connection with branch lines but under certain circumstances with the taking over of a part of a main line service. It will however only be permissible to set up a motor vehicle service of this description, either if it would materially increase the traffic on the railway by serving places at a distance from the rail, or if it is capable of supplementing the rail time table in a more efficient manner than could be achieved by the running of additional train services. The introduction of a suitable motor transport service can under certain circumstances be designed to retain the rail traffic which is threatened by a competitive service.

The Reichsbahn has up to date set up 57 passenger motor vehicle lines of which 11 are run by the Reichsbahn and 46 are run by arrangement with other undertakings. The economic result is satisfactory as the lines in question were selected with a view to their capacity to give a substantial return.

The question as to whether it is more economical to run motor bus services themselves or to have them run by other undertakings can in accordance with the experience hitherto gained by the Reichsbahn be answered with some confidence to the effect that it is cheaper for the Reichsbahn to run such services itself, provided such services are limited to those which can be worked from railway bases without the need of heavy staff costs. Generally speaking this should be kept in mind by all railways who wish to undertake ther own road motor services.

If the Reichsbahn has by a recent agreement which has been concluded with the German Postal Service, renounced the right to install its own passenger motor vehicle services and seeks future activity exclusively in the shape of joint working with the German Post Office, it is because the advantages of such cooperation appear to lie less in the direction of increased economy for its own motor services than in the means which the agreement provides of influencing the development of the Postal Motor Service which is by far the most important undertaking of its kind in Germany.

The agreement has also for its object the achievement of the greatest possible unification of overland transport, which has hitherto been very much split up. This is an aim which will not only be in the common interest, but also most desirable from the railways point of view, as it has become abundantly clear that the large number of independent motor bus undertakings has been one of the contributing causes for the existence during late years of such large numbers of competing lines.

The agreement will further enable the Reichsbahn to participate in the earnings of the new road mail transport service which will shortly be instituted, and in this manner to obtain a certain amount of compensation for the loss it has suf-

fered through the existing competitive motor transport services.

Finally there is a further advantage for the railways which is not to be underestimated, namely that they will indirectly participate in the unrestricted right to concessions which has been given to the German Post Office by law.

The following details of the agreement may be worth noting :

The new motor transport lines will be run by the Post Office in joint account, in such a way that the Reichsbahn will participate in the profits or losses according to a proportion to be determined beforehand. A distinction will be made between lines competing with the railways and other lines. A motor transport line, according to the agreement, is to be considered as a competing line, if it provides direct transport between points already served by the railway, and if such a competing line having a total length of 30 km. (18.6 miles) is up to 15 % longer or shorter than the railway section in question, and if the competing line has a greater length than 30 km., when its length is 25 % greater or less than the railway section. If a competing service exists, then the Reichsbahn shall decide whether or not a motor service shall be set up under the agreement, in all other cases the Post Office shall have the right to make the decision. If the Reichsbahn wishes to utilise any transport line run by the Post Office, which it is free to do if it so desires, then in the case of a competing line the Reichsbahn will share as to 65 % and the Post Office as to 35 % of the profit or loss as the case may be.

With other lines and with special services the proportions are reversed. The agreement further contemplates mutual support, more especially in regard to the common use of fuel tank installations, garages and workshops. The Reichsbahn will allocate special positions to the Post Office for parking their omnibuses outside the railway stations, will permit passengers to use the waiting rooms and will supply ticket offices and luggage registration for the omnibus traffic. For traffic peaks and emergencies, the Reichsbahn and Post Office will assist each other with personnel and stock. Through bookings, both for passengers and luggage over railway and omnibus sections, are provided for. The Reichsbahn and Post Office undertake to support each other in competition with third parties. As against this the German Post Office under the same agreement definitely surrenders in favour of the Reichsbahn any claim as regards the working of motor borne goods traffic.

It remains to be seen how this agreement, which has provisionally been fixed for a term of five years will work out in practice.

As regards *goods traffic* and apart from alterations in tariffs which will be referred to later on, improvements and simplifications in the despatch and forwarding services are announced with a view to meeting competition. Measures of this nature have already been carried out to a large extent on the Reichsbahn system, and generaly with good results wherever it has been the question of fighting competition, where undercutting has not been too great.

Among the steps taken are : extension of hours for acceptance and delivery of goods, arrangement of Sunday and holiday services for delivery of perishable goods, simplification and speeding up of loading and dispatch by increased mechanization of this work, greater facilities at junction points, increase in num-

ber and speeding up of train connections, reduction of transhipments on the road and many other matters. In certain cases container traffic should enable the Railways to meet mechanical transport competition. Successful trials of this method have already been made on a number of traffic routes in Germany. Up to now this innovation has not yet been so far developed as to enable a definite opinion to be formed of its value.

The employment of motor transport by the railways themselves for goods traffic may prove a further means of reducing competition by outside motor transport provided that the competition is based on the special advantages which the motor vehicle is able, for technical reasons, to offer to consignors and is not merely due to price cutting against the Railway tariffs. With few exceptions the substitution of motor vehicles is properly restricted to short distance traffic. In this connection the condition governing goods traffic comes into consideration both in districts served by branch lines of railway as well as those served by main lines. In the same way a suitably developed feeder service may under given circumstances ward off competition which may be threatened from another quarter. Taken as a whole, however, the possibility of using the motor lorry economically in the service of the Railways is relatively small.

The main reasons for this are as follows:

In respect of traffic from works and factories which is, as stated above, for the most part short haul traffic, it is difficult to guard against competition because the users of mechanical vehicles are in many cases only concerned in an extension of their existing complement of lorries which are in use for local transport and because one advantage of using their own motor lorries is the fact that they are thus able to keep in closer touch with their customers, a circumstance which is very desirable for them. On the other hand, the competition of motor transport run as an independent business, bears very heavily on the Railways owing to the large number of small vehicle owners, who run services at very low prices and very often obviously work at under actual cost price. It is very rarely possible to achieve an effective saving in the cost of railway traffic by replacing it by motor lorries. Even in the case of branch lines a saving is not always effected, because it is hardly ever possible to make a reduction in the existing goods depots, if small goods traffic handled by one or other of them is taken over by motor lorry service. In accordance with the experience of the Reichsbahn, conditions are more favourable for the economical use of motor transport in the local traffic of the big cities, where the lorry may be utilized as a connecting link between the various stations and where road transport as opposed to rail transport may lead to a substantial shortening of the haul.

Up to date the Reichsbahn has instituted a total of 43 motor vehicle operated goods services, of which 14 are run by the railways themselves, while 29 are let out to sub-contractors.

According to the experience so far obtained with goods traffic it is found that it is generally speaking preferable for the railways to work their own motor carried goods traffic, than to let it out to third parties.

While cooperation of the railways with those operators already in the motor traffic businesses can only rarely be considered, such cooperation between Railways

and carriers must not be expected to lead to any appreciable reduction in competition. Agreement as to spheres of operation may perhaps prevent one or other of the outside commercial undertakings from setting up serious opposition, but such agreement would have no influence in the development of motor traffic in general. While such an agreement might be practicable with a small number of firms, there would still remain the competition of the large majority of other motor transport interests in particular the large number concerned with works, industrial and trade undertakings. It must be clearly understood that any such agreement will mean that the motor transport owner must be prepared to renounce the profit which is possible for him owing to the provisions of the railway goods tariff, and in consequence it is unlikely that any owner will be got to agree unless he can see a chance of being able to make some profit out of an agreement.

This opinion is moreover confirmed by the experience of the Reichsbahn in connection with a four-year contract which was made by them with the mechanical transport companies formed jointly with the State and principalities. This agreement was cancelled in the autumn of 1928 because it did not fulfil the expectations of either party.

In view of the fact to which attention has been called above, that competition by the motor lorry, especially where it is a question of long hauls, almost always arises from its ability to under cut the railway goods tariff for intermediate sections of the route, it is evident that the most important and in many cases the only measure that the railway can adopt lies in the introduction of *reduced railway rates*. In view of the present extent of road competition such measures as a tariff reduction for certain classes of goods or a general reduction within certain fixed distance zones, can therefore not be recommended. In the case of both alternatives, the loss of income and likewise the reaction due to these protective measures on the tariff system and thus also on the industry as a whole, would be much more far reaching than the effect of the un-restricted motor transport competition itself. There can at present therefore only be a question of special tariff rates of an exceptional character which would be operative for particular transport arrangements or types of goods. Naturally care must be taken that the object of these measures is really attained, that is to say that the particular traffic is retained or regained by the railway and that moreover, with a result in terms of money which is more favourable than would be the case if the diversion of traffic took place without the introduction of reduced tariffs.

The Reichsbahn has, during the last few years, introduced a number of so called K tariffs (motor transport competition tariffs) which have throughout been successfull in fighting competition. At the present moment 150 such tariffs are in operation in transport sections threatened with competition and these are more particularly applied to certain special classes of goods, as for example, paper, cereal and flour products, sugar, wine, beer, mineral water, cement, bricks, hardware, etc., these goods, being as has been shown, particularly favoured by motor transport competition.

In addition several K tariffs have been instituted in connection with the collecting traffic of forwarding firms, and again only where certain freight conditions are seriously threatened by lorry

competition. Quite recently a general reduced tariff for such forwarding business has been provisionally fixed for a period of one year, thus supplementing the exceptional tariffs hitherto individually imposed. This reduced tariff applies to goods carried from and to all stations of the Reichsbahn over distance of from 100 up to 400 km. (62 to 248 miles) and has for its object, to renew the interest of the forwarding agents in this collecting business which was formerly considerable, but which owing to the influence in late years of road transport competition, has fallen off very greatly.

The tariff reductions hitherto given under the K scheme vary considerably in degree. On the average the K tariff constitutes a reduction of from 25—30 % on the standard rates. There are however other reductions in force which are either greater or less in amount but in every single instance the reduced rates remain above the actual cost to the railway.

It must be clearly recognised that the K tariffs are purely a make-shift, so long as the Reichsbahn and other German Railways continue to be legally prevented from fixing their tariffs freely in accordance with requirements as well as from making special contracts in order to meet competition by motor transport. This freedom must in time to come also be obtained for the Reichsbahn for it is clear that owing to the growth of the motor lorry business, the transport monopoly hitherto enjoyed by the railways has ceased to exist and with it the necessity for the legally imposed obligation that the railways must make public all tariffs, including such special rates as may be made to meet competition under particular conditions, and that these tariffs must be equally applicable to every person without differentiation. The removal of this obligation and further the granting of permission to make special rate reductions in favour of individual clients, where competition exists, would materially help the railways to meet competition. The more freely the railways can meet the price cutting of the motor transport operator, the more it will be able to limit the total amount of its price reductions, and the less will be the effect of the protective measures on the tariff system of the Reichsbahn and on industry in general.

APPENDIX I.

According to the Official Statistics the number of Motor Vehicles in Germany was as follows:

Year (1).	Number of				
	Motor bicycles.	Small motor bicycles.	Omnibuses.	Passenger cars.	Total passenger vehicles.
1914	20 611	...	...	55 000 (3)	75 611
1921	26 666	...	...	60 611 (3)	87 277
1922	38 048	...	1 755	84 937	124 740
1923	59 389	...	1 753	98 587	159 729
1924	97 965	...	1 833	130 346	230 144
1925	161 508	...	3 220	171 445	336 173
1926	235 186	26 943	5 086	201 401	469 832
1927	295 186	44 040	6 632	261 142	607 000
1928	334 314	103 974 (2)	8 596	342 668	789 668
1929	385 863	222 479	10 593	442 612	1 041 747

(1) According to extent of territory on 1 June 1928. The figures for 1914 are estimated.

(2) A part of the increase of light motor bicycles has to be debited to the earlier increase of the heavy motor bicycle. The regulations in regards to motor traffic issued on the 16 March 1928 widened the limits of the light motor bicycle.

(3) Includes motor omnibuses.

APPENDIX 2.

Number of motor lorries in Germany.

—	1922		1923		1924		1925		1926		1927		1928		1929	
		%		%		%		%		%		%		%		%
Total motor lorries	43 711	100	51 736	100	60 629	100	80 363	100	90 029	100	100 969	100	121 765	100	143 952	100
of which :																
Up to 1 000 kgr (2 200 lb) tare weight	3 135	7.2	3 823	7.4	4 915	8.0	8 486	10.6	9 736	10.8	12 834	12.7	15 971	13.1	18 015	12 5
Over 1 000 kgr. and up to 2 000 kgr. (4 400 lb.) tare weight .	5 356	12.3	6 630	12.8	9 006	14 8	17 900	22.3	23 472	26 1	30 964	30 7	43 539	35.8	59 179	41.1
Over 2 000 kgr. and up to 3 000 kgr. (6 600 lb.) tare weight .	4 711	10.8	5 658	10.9	6 465	10.7	8 625	10.7	9 506	10.6	10 101	10.0	13 435	11.0	17 093	11.9
Over 3 000 kgr. and up to 4 000 kgr. (8 800 lb) tare weight .	11 955	27.3	14 490	28.0	16 802	27.7	19 649	24.4	20 010	22 2	19 029	18.8	18 305	15.0	17 746	12.4
More than 4 000 kgr. tare weight.	18 554	42.4	21 135	40.9	23 441	38.7	23 703	32.0	27 305	30.3	...	...	...	...	...	...
Over 4 000 kgr. and up to 5 500 kgr. (11 000 lb.) tare weight.	...	...	...	...	...	...	...	...	...	...	25 361	25.1	25 511	21 0	24 647	17.1
Over 5 500 kgr. (11 000 lb.) tare weight	...	...	...	...	...	...	...	...	...	...	2 680	2.7	5 004	4.1	7 272	5.0
Tractors without goods space .	342		383		1 026		7 731		10 263		13 706		19 007		25 095	

In 1914 motor lorries were not statistically divided in classes by size. The total at that date was 9 071 vehicles.

APPENDIX 3.

Employment of passenger vehicles.

DESCRIPTION.	1922	1923	1924	1925	1926	1927	1928
Motor bicycles	38 046	59 389	97 965	161 508	263 345	339 226	438 228
Passenger vehicles.	...	..	...	...	...	...	...
Public taxis.	7 160	7 291	7 500	10 574	15 306	20 055	22 343
Postal buses in public traffic	866	908	1 212	1 678	2 354	2 714	3 058
Road transport undertakings, buses in public traffic.	...	....	...	..	748	972	1 075
Other buses in public traffic	889	845	621	1 542	1 984	2 946	4 483
Passenger cars in official traffic.	3 821	3 075	3 000	3 794	4 239	4 303	5 227
Other passenger cars	69 956	88 221	119 846	157 077	181 856	236 284	315 214

Employment of goods motor vehicles.

DESCRIPTION.	1924	1927	1928
Motor lorries.			
Up to 2 tons tare weight	13 921	43 798	59 510
Over 2 tons tare weight For official service	4 426	5 732	6 760
Farm and forest service	2 081	2 185	1 959
Public transport traffic	6 104	7 355	10 213
Commercial and other uses	34 097	41 899	43 325
Miscellaneous uses and tractors without goods loading room	1 026	13 706	19 907
Fire engines and municipal street cleaning vehicles	2 233	2 260	2 872

[388 .524]

REPORT No. 3

(All countries except America, the British Empire, China, Japan, Belgium, France and their Colonies)

ON THE QUESTION OF THE CO-OPERATION OF THE STAFF TOWARDS INCREASED EFFICIENCY AND ITS PARTICIPATION IN THE PROFITS (SUBJECT XV FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION) (1),

By Rafael MARIN DEL CAMPO,
Engineer of the Board of Directors of the Madrid to Saragossa and Alicante Railway Company,

and Juan CANOVAS DEL CASTILLO,
Principal Engineer, Headquarters of the same Company.

SUMMARY.

I. — Introduction.

When the Permanent Commission of the International Railway Congress Association did us the honour of appointing us as reporters on Question XV for the countries indicated above, our first reflection was that we should have, before all, to ascertain the exact significance of this question, in order thus to be able to draw up in a satisfactory manner the detailed questionnaire which we should have to submit, through the channel of the said Commission, to the different railway administrations. This preliminary study was the more necessary, since the question XV will not be dealt with in any of the special sections of the Congress; neither the 1st, 2nd, 3rd nor 5th, but in the 4th section, which will have to concern itself with all questions of a general character or order. Moreover, it was imposed on us by reason of the form, at the same time wide and vague, in which the question at issue was formulated.

The wording of this Question XV: « Co-operation of the staff towards increased efficiency and its participation in the profits » everyone probably knows what that means *grosso modo*, but perhaps people in general have not asked themselves why this subject thus formulated *figures in the programme of the sessions of the Congress*, and for this reason all will not have had the opportunity of preparing an exact reply to this latter

(1) Translated from the French.

interrogation. If we are probably all in agreement to reply that the essential objective that it is proposed to attain by interesting the staff, as far as possible, in the railway revenue and profits is to increase the prosperity of railway enterprise, we shall, on the contrary, divide ourselves into as many groups of opinions as there are different conceptions of this expression: « *railway enterprise* », and before all of the more general one which embraces it, i. e. *industrial enterprise*, since the railways are nothing else than one of the most important industries, intended to produce and sell the merchandise known by the name of *transport*.

Thus, some say: « *Industrial enterprise* consists of manufacturing the goods or product in question at the lowest possible cost price, and selling it at the highest price permitted by free competition ». Such has for long been, and such still continues to be what might be called the *classic conception* of industrial enterprise. The most important practical consequences of this theory, or, in other words, its distinguishing characteristics, are: the greatest possible gain, *per unit of product manufactured*, for the manufacturer; wages as low as possible, and high selling prices. To attain this end, one is led to fight by all means the competitive regime, that is to say, to employ all the means at one's disposal to prevent the downwards movement of the selling price. This struggle against competition is manifested in the most noticeable manner by the formation of trusts and other similar combinations.

These consequences, derived from the conduct of industrial enterprises built up in accordance with the classic theory or conception of which we have just spoken, provoked in the public a reaction against the owners of these undertakings, and it was decided to be desirable to try, on a larger or smaller scale, the system of *cooperative production* organisations amongst consumers, with a view to dispensing with the manufacturers; on the other hand, by irritating the working masses, they constituted the veritable germ and the principal element in the success of Socialism.

We may find, without going out of our professional world, a striking example of the first of these two systems in the numerous, large and sometimes gigantic *State Railway administrations* which we know, and which, looked at closely, are neither more nor less than co-operative societies for the production of the merchandise known as transport, of which the citizens are the partners or shareholders, and of which the respective States exercise the management. And an example, not less striking, of the second case is the Russian communistic *experiment*, which is only a variant of the socialist system. It is convenient, of course, to qualify as *State Socialism* the creation of the great railway systems attaching to the first group, and to rank under the generic appellation of socialism the two groups of examples cited, a name applied indiscriminately in the two cases, for they both originate from a like conception of affairs, the *socialist conception*, born of the desire to destroy the consequences flowing from the *classic capitalist conception* of business, to the detriment of the working masses as well as of the public in general.

Circumstances of which the exposition and analysis would not be here in place have recently led to a conception of industrial enterprise which few people can have formulated with as much success

as Mr. Henry Ford, if in fact anyone has succeeded in doing so, in word and in deed, under conditions comparable with his. To sum it up, this new conception, which might be called the *harmonic conception*, consists of considering an industrial business as a harmonious association of three partners : the capitalist, the workers and the public, all the three of which should be equitably benefited ; in other words, the system must tend : 1. to remunerate the workers by higher and higher salaries, so as to improve, progressively, both their working and social conditions; 2. to reduce unceasingly the selling price of the products manufactured ; 3. to increase simultaneously, and following an increasing progression, the profits of the capitalist. This *harmonic conception* of affairs, far from being Utopian, appears praticable and — better still — a corollary of the modern *scientific conception* of industry.

The characteristics of the *classic conception* of affairs being those indicated above it is clear that what distinguishes them is the opposition between the interests of capital, on the one hand, and those of the paid workers and the public, on the other hand ; the *socialist conception*, on the contrary, is based on the suppression of the individual capitalist or manufacturer, for whom it substitutes collective ownership, which would thus be at once producing and consuming, integrally ; finally, what we have designated, to give it some sort of name, as the *harmonic conception*, tends to participate simultaneously in the spirit of the two foregoing ; it is, in effect, capitalist like the first, in the sense that it does not eliminate the capitalist, but continues to confer on him initiative and command, and it is socialist, like the second, in the sense that, to this initiative and control, it assigns in a concrete and scientific manner, as an essential objective, the simultaneous and concordant prosperity of all the producers (capitalists and paid workers) and consumers (paid workers and public), for it is well to remark that the partisans of this lastnamed conception comprise amongst the consumers, sometimes even for preference, the operatives who work in the industry in question, and that often, even, for the products it manufactures.

So far as concerns, in a concrete manner, the railways, the conceptions which, up to the present, have on the whole crystallised out in the domain of practice are the two first ; however, one must not disregard the fact that the very modern third conception has also commenced, on a small scale, it is true, to introduce itself into the realities of railway life.

* * *

Let us now examine, in the light of what has been set forth above, the true significance of the ideas and practices designated under the name of *premiums, bonuses, special promotion, various rewards and facilities for the acquisition of railway stock*, which are or may be granted to the staff to stimulate its zeal and activity.

In the *classic conception* of the railway industry, premiums, bonuses etc., are accorded to the end, not precisely of favouring the public or the staff, but of stimulating the latter principally and essentially to the benefit of the master. In the *socialist conception*, these premiums, bonuses etc., cannot be of profit to the individual capitalist, who does not exist ; they do not tend, either, to fa-

vour the staff, but only to stimulate it to the profit of the reduction of the selling price of the transport product and of good service, i. e. of the public. Finally, in the *harmonic conception* of the railway industry, the premiums, bonuses, etc. are granted also to stimulate the staff, but with the concrete design of reducing the cost price and of improving the service, not exclusively to the profit of the master, or of the public, or of the worker, but to benefit the three simultaneously in an equitable manner, i. e. by earmarking a part of the economies realised for increasing the liquid resources of the enterprise, another part for lowering the tariffs and for increasing the facilities and improving the traffic conditions, and a third for raising the rates of pay. To express ourselves in a manner more synthetic and more exact, we shall have to say that the harmonic conception of industrial affairs leads automatically to the *increase of the purchasing capacity* of society in general, and *simultaneously* of the individuals forming it, and this becomes from day to day less impossible, thanks to the scientific and ever more extended use of natural forces.

As is pointed out by the protagonists of the *harmonic conception* of industrial enterprise, its interesting side, or — to express it better — its essential side is the rational basis of the system. They assure us that in its origin it is not inspired with a philanthropic spirit, and that if, in fine, the system is philanthropic, the fact is that it is only a question of a *scientific conception* of affairs, born, rather than from sentiments of love towards the worker and towards humanity, from the conviction that this doctrine, conceived by capitalists, is the only one which responds to the present needs of civilisation, and the one which, at the same time, can produce greater output and profits. For all these reasons, that is to say, owing to the rational strength of its principles, and because it conduces, according to those who support it, to increase simultaneously the material and moral prosperity of the capitalists, the paid workers and the public, its partisans conclude by the affirmation that the *harmonic conception* of affairs and the rules deriving from it will not be long in eliminating from industrial life the methods in use up to the present, offspring of the *classic conception* or of the *socialist conception*, or of the badly designed combinations which have been made or may be made of the two.

The partisans of the most modern school assert also that the premiums, bonuses, etc. accorded to the staff in the industries in which the classic conception of affairs reigns constitute a system characterised by narrowness of view and meanness, which, in their opinion, are still more pronounced in the industries ruled by the socialist conception, in which the ideal would be the absolute suppression of the said premiums, bonuses, etc., whereas these tend to be lavished in an extensive and magnificent manner, although on other bases, in the industrial organisations regulated by the harmonic conception of affairs. And they mention amongst other proofs in support of this latter assertion the fact that the technicians: managers, engineers, chemists etc., who discover or invent any device or process securing, for example, a considerable economy in the costs of production, are royally remunerated, and from the start earn salaries much higher on the average than those commonly allotted in the industries

in which the classic or socialist conceptions prevail. « We are not inspired », they say, « by a sordid and in fact sterile and miserly egotism, nor, on the other hand, by an Utopian humanitarianism, today at least; we take Science for our only guide ».

* * *

Such were the first reflections that presented themselves to our minds when we received the nomination as reporters. Under their influence, we set ourselves to review the complete collection of the *Bulletin* of our Association, and to read attentively the reports of the questions analogous to Questions XV of the Madrid session of the Congress, which were the subject of papers and of discussions in previous sessions, and constitute precedents which we consider ourselves obliged to take into account.

We will therefore commence the body of our report by a very succinct summary of these reports. Subsequently, we will cite certain important works which have appeared likewise in the *Bulletin* of our Association, and which, without forming part of the minutes of the sessions of the Congress, may be considered as suggestions made by the Permanent Commission so that we may all take account of them. We will afterwards give an idea of one of the realisations which the harmonic conception or theory of industrial affairs has already achieved, on a small scale so far, it is true, in the domain of railways. We will go on to speak of the replies which the different administrations have addressed to us. And finally, as a conclusion to all these details, we will submit to the 4th section of the Congress the proposals which we judge to be the most useful and opportune.

II. — Papers presented and resolutions adopted on this question in the previous sessions of the Congress.

The question of the participation of the railway staffs in the revenue and profits of the enterprise was raised for the first time in the second session of the Congress (Milan, 1887). It was returned to in the second session (Paris, 1889). Then, apart from a few minor and unimportant indications given in subsequent sessions, the subject did not figure in the questionnaires of any other session. Resuming consideration of this question today, therefore, it is well to take account of the fact that it has not been discussed by our Congress for forty-one years.

A. — *Second Session, Milan 1887.*

In the course of this session, the question was discussed in two different sections :

In the second section, *Locomotives and Rolling Stock*, Question XI was headed as follows : « *XI. Premiums. — What is the best system of premiums employed for the repair of rolling stock and for locomotive service ?* »

The report is reproduced in the number of the *Bulletin* for August 1887, (French edition), and the discussion and conclusion are given in the number for March 1888 (French edition).

Beyond the fact that we learn there that the premium system on railways was adopted about 1844 or 1846 by the Strasbourg-Bâle line, with other facts not devoid of interest, we can find in the discussion opinions which are estimable indeed, but not altogether transcendent, with regard to the advantages and draw-

backs of the different systems of premiums of the kind in question.

The conclusion approved by the General Meeting was the following :

It appears advantageous to compose the remuneration of the driving staff of locomotives — enginemen and firemen — of a fixed part, ensuring suitably their means of existence and their future, and a variable part, increasing with the personal work and the efforts of each with a view to giving a service satisfactory to the public, while being economical for the Companies.

In the fourth section of the same session of Milan, 1887, *Questions of a general nature*, Question XXI was set forth as follows : « *XXI. — Remuneration of employees. — What is the best means of remunerating the employees, and of interesting them in the economies of working ?* »

The report appeared in the number of the Bulletin for August 1887, and the discussion and conclusion in the number for June 1888 (French edition).

Those who spoke on this theme dealt largely with the theme of economic management and with cooperative ideas, but not much with that relating to salaries ; and as regards the premiums, it appears to us that the discussion wandered a little, in spite of the care with which the question had been framed, as is natural with a question of greater generality than in the second section of the same session of Congress, of which we have just spoken. Finally, the examination of the subject was left in only a slightly advanced state, and it was therefore proposed to revert to it in the third session after better and more thorough preparation, which as a matter of fact was done.

The conclusion approved in plenary session was simply the following :

The Congress admits that when, for any reason, the individual initiative cannot have free play, economy premiums and other institutions of a similar nature are to be recommended, on condition, however, that they are never obligatory and that all the measures to be adopted tend to disengage the Administrations from a supervision which is not without danger, and to develop the action of the co-operative societies, free from all direct interference from the Administrations, a desideratum to which our incessant efforts must tend.

B. — *Third Session, Paris 1889.*

In the Fourth Section, *Questions of a general nature*, Question XX was thus framed : « *XX. — Premiums to staff. —* Means of interesting employees in economies in working expenses and in the increase of receipts. »

The report figures in the number of the Bulletin for August 1889, and the discussion, with conclusions, in the number for August 1890 (French edition). There were, as appendices, an interesting note on the Russian railways, published in the number of February 1889 (French edition), and three other notes on various railways which had appeared in the August number of the same year.

The report, as well as the discussion, of this question in the Paris session were very interesting, and, needless to say, more complete than at the Congress of Milan. Their attentive perusal affords many explanations, both on the distinction between bonuses and premiums properly so called, and on the analysis, the utility and the drawbacks of pre-

miums from the point of view of the increase of the gross product, or of the net product, or of economies in the different services (general charges, working, traction, material, track etc.), also on other points.

It is right that we should note the favorable impression produced by reading the report of Mr. Bela Ambrozovics, Ministerial Councillor of Hungary, not only because his work has much value from the orderly, clear and competent nature of the exposition, but also because, for the first time, he shows the importance of the questions of organisation and of moral order with regard to the subject studied by him. Hereunder we reproduce a few significant phrases of the said report :

At Milan, the Congress did not discuss the question in its full extent. Only the question of « Premiums for economies » was sounded to some degree, while the question of the increase of receipts by the constant solicitude of employees was not given a direct place in the discussions; it was only treated incidentally and on my proposal. The debate remained within the limits of generalities, and even as regards premiums for economies in expenditure, principles were insufficiently developed. It is therefore necessary to envisage the question once again in its integrity, and this it is which has decided the International Commission to place it anew on the programme for the third session of the Congress...

The matter of sovereign importance is, in my opinion, to lead the staff to identify its interests with those of the enterprise *as a whole*, and in a subsidiary degree to develop in the staff the speculative and commercial spirit in the interests of the enterprise. This is quite another thing from urging the staff to interest itself *temporarily* in the results of a single branch of the service, and from developing in it the spirit of *gain*...

It may be said that there is hardly one of the servants of a railway who could not render to the enterprise, in one way or another, a service exceeding his strict duty. By interesting them all in the prosperity of the enterprise, by making them identify themselves with it, each of them will find, according to his faculty, according to the position which he occupies in the service or outside the service, the proper means to advance, more or less, the interests of the enterprise...

When it is a question of attaining an elevated goal, one must not quibble over points of detail or be too heedful of trifles. Imperfection is a property common to all things, in this world, above all when it is a matter of judging the acts of men — does not justice sometimes strike the innocent? Do all employees, without exception, earn their pay? Are there not those among them who save appearances, and dexterously convey the impression of working a lot without even doing their duty? To desire an infallible system is to seek the impossible...

To apply the system of participation in the proceeds of industrial enterprises is to interest the employees in the results of bad years as well as good, and to render them shareholders in the enterprise; does not this tend to reconcile capital and labour, and does it not accelerate the solution of one of the gravest questions debated in our day? For if this struggle has always existed since society existed, it has at least never been more inflamed than now...

When it is proposed to seek the means of interesting the staff in the prosperity of the enterprise by looking for inspiration amongst the flood of ideas which respond to the modern conception of things, always ready to presume a material motive in human action, the possi-

bility is almost forgotten of having recourse to other means serving the same end...

If money counts for much in life, it is not *everything* in human affairs. There are cases where a position less advantageous as to money is preferred to one more brilliant, for reasons of a purely moral order...

Self-esteem and affection for superiors result from good treatment, which is one of *the most essential conditions* for keeping the personnel of an enterprise content and for inducing it to identify itself with that enterprise; there go along with this all the means proper to maintaining and increasing ambition, *esprit de corps*, mutual consideration amongst the personnel, etc., etc., all of which serve to render service relations agreeable...

Two things, *bureaucracy* and *centralisation* — of which we do not know which is the cause and which the effect — are detrimental, from this point of view, to railway interests...

Bureaucracy, as also centralisation, over and above the expense occasioned by the complication of the service, stifle the practical sense and the spirit of initiative of the employees, without which the railways cannot respond to what we have the right to expect of them. Further, they deprive the staff of the desire and even of the possibility of interesting themselves sincerely in the development and prosperity of their employers, the Companies...

This is also the main reason which dictates the rejection of the premium system when it is limited exclusively to the directors and chiefs of service. The monopoly of material reward conduces to a moral monopoly, i. e. to bureaucracy and centralisation...

One should adopt as a maxim : « Write as little as possible » and enforce the principle of personal responsibility. Amongst the things which are little calculated to improve the sentiment of honour the staff and to stimulate ambition, extreme control can still be ranked...

It is very difficult to say which should be preferred of the systems here dealt with. That depends to a great extent on circumstances, and a method applied with success on one railway may be inefficacious on another. The best thing would be for each Administration, accepting the principle, to combine the elements brought out during the course of the discussion in Congress so as to form a complete and harmonious system, and to commence within a narrow framework adapted to the respective circumstances of the railways, ready for enlargement as occasion demands. That would be my conclusion, if I had to propose one to the Congress. What is beyond all doubt is that this question is of extreme importance, and that no reasonable means should be neglected to stimulate the zeal of the employees and to incite them to interest themselves in the prosperity of their employers, the railways.

In the discussion of the question and of the report, the circumstance is worth noting that to the majority of those who took part the fact did not appear very agreeable that M. Ambrozovics attached a great importance to organic and moral questions. Reading today, this discussion, at a distance of 41 years, produces the impression that Mr. Ambrozovics, perhaps in advance of his time, was of a type of mind superior to those who received so badly, as it appears, his organic and moral conceptions. At the present day, in 1930, the welcome offered to the ideas of Mr. Ambrozovics would assuredly be quite different, for even the capitalists, the large firms and high functionaries who, formerly, only took account of financial and technical data, are today

unanimous in recognising the enormous and transcedent place that organic and moral factors occupy in the problem of the participation of the personnel in the revenue and profits of a railway, as of any other industrial enterprise.

Here are the conclusions then approved in plenary session :

The meeting is of the opinion that outside of the means of a moral and material order (provident institutions, etc.) calculated to maintain the necessary bonds of solidarity between the Companies and their employees, premiums for economy, bringing into play their personal interests, are one of the best means for developing the efforts of the employees, in the direction of improving working results.

The meeting remarks, in the first place, the difference to be established between *bonuses*, properly so called, which recompense exceptional efforts or services, not susceptible of exact measurement, and *premiums*, which can be applied to economies realised on expenses which it is possible to evaluate more or less exactly. In this order of ideas, the assembly completely rejects the idea of premiums based on the development of gross receipts, by reason of the difficulty of determining exactly who are the servants who can influence such development, and above all of measuring such influence.

Premiums based on the increase of net working receipts (and not on the increase of the dividend), after setting aside the capital charges, on which the operating services have no effect, would be less difficult to establish; it appears preferable to the assembly, however, by reason of the influence of the gross yield on the working receipts, to adopt here the form of a bonus, the total amount of which, determined by the Boards, would be distributed by the directors amongst the various operating services and by the chiefs of these services amongst the employees who may have been able to contribute to the increase of the net receipts.

With regard to operating expenses, the assembly considers that these comprise, in very large number, elements susceptible of more or less precise determination, either directly or by the results obtained in one or more previous financial years, and that for all these elements it may be very advantageous to establish premiums based on the saving realised on a wisely determined allocation. The bases of these allocations must be revised from time to time, to take account of the results achieved, the share attributed to the employees in the savings realised having to be increased as the allocation is reduced.

The meeting considers that premiums alloted to aggregates too large in number are not advisable, the reciprocal supervision of the employees over each other becoming impossible. It thinks that the premiums must be direct, and paid so far as possible to individuals or to very small groups. It thinks it inadvisable to limit them in advance to a maximum; if they appear excessive, it is preferable to revise the bases of the allocations. It adds that, in order to produce their full effect, premiums must be credited to those entitled to them as soon as possible after the settlement of the operation to which they relate.

The meeting is of opinion, finally, that if, in the operating services, there are a very great number of elements susceptible of evaluation in advance and of premiums for economy based on a predetermined allocation, it is well to avoid those premiums which would be liable to compromise safety, and in particular only to apply them with prudent reserve to the service of permanent way maintenance, economies in this respect being possibly realisable by neglect of measures absolutely indispensable to safety and to the good preservation of the track.

III. — Some works worthy of mention, published in the Bulletin of the Railway Congress.

The *Bulletin* of our Association has also published or noticed some important works on the subject studied in the present report.

In the number for May 1895 (French edition), pages 1632 to 1634, there appeared a short but interesting note by the Southern Italian Railways, in which they give an account of the recent creation of a special premium system, the object of which was to ensure economy in station working and in the handling of goods, an economy obtained, thanks to the allocation of the said premiums to the staff, on the surplus of the annual budget of each important station.

The number for December 1896, pages 1222 to 1227, contained an instructive note concerning the Russian Railways, in which there are demonstrated, with documentary support, the advantages of the premium system over others in the services of loading, unloading, transhipping, receiving and delivering goods and luggage, vigilance in transit and in the stations, also in other various station services, such as the consumption of books and printed matter, the cost of travelling expenses of the employees of the commercial service, of those charged with the shunting at stations, with firing, lighting etc.

The number of August 1897, page 1229, reproduced a circular of the Minister of Public Works in France on the subject of train speed recording apparatus and the premiums for regularity and economy in France. In the said circular, addressed to the Boards of Directors of the railway companies, it is certified from an authorised source that such premiums are not incompatible, as some believe, with the safety of traffic, whether use is made or not of recording apparatus.

In the number for January 1898, pages 3 to 18, there appeared a communication addressed by Mr. Schmidt, Engineer of the Russian Railways, to the Xth Consultative Technical Assembly of the General Railway Conference of that country. It is well worth reading, for it demonstrates theoretically and practically the possibility and the utility of economy premiums in permanent way service, and refutes what is said on this subject in the last paragraph of the conclusions quoted above of the session of our Congress of Paris, 1889. In the same order of ideas, a very remarkable case is that mentioned by the same Mr. Schmidt (page 8) : we mean the conversion of the engineer, Mr. Ast, who, previously hostile to the premium system, as were the members of the Paris Congress, ended by becoming its defender.

In the number of September 1898, page 1075, and under the title : « Cooperation on the railways », there is a note giving an account of the facilities which the Illinois Central Railway Co. accords to its employees to permit them to acquire shares in that Company at special prices and on special terms, with the result that the interests of the said Company, its employees and the public have reaped benefit.

In the number of March 1903, pages 187 to 197, there appeared an article from the pen of Mr. Rimestad, Director of the Danish State Railways, on the reorganisation of those railways. The third part is entitled : « Participation in profits ». This participation consists of allotting to the employees so much per cent of the annual profit of the railways, distributed according to grade; the

said percentage is fixed in accordance with a decreasing scale as the profit realised increases. The most interesting thing in this study is the statement of the considerations into which the author enters to justify the adoption by the Danish railways of participation in profits (pages 195 and 196). This work is only an extract of a proposal of the mixed Parliamentary Commission nominated in 1898 to study the reorganisation of the said railways ; further, as is stated in the August number of the *Bulletin* (1903), page 794, this proposition was adopted by the Parliament, with slight modifications of a secondary order.

Special mention is due to the discussion constituting a series of three articles inserted in our *Bulletin* in 1913. The first appeared in the March number, pages 200 to 206, under the title : « Are we ready for industrial co-operation ? », by Fairfax Harrison, president of the Chicago, Indianapolis & Louisville Railway, member of the Permanent Commission of the International Railway Congress Association. The second article, which figures in the September number, pages 731 to 734, bears the following title : « Note on Mr. Fairfax Harrison's scheme for industrial co-operation » by Lionel Wiener, Director of the Société Balkanique d'entreprises générales. Finally, in the December number, pages 995 to 1004, there appears the third entitled : « Mr. Fairfax Harrison's scheme of industrial co-operation applied to the railway operation », by H. Marchand, electrical engineer, Brussels.

These three papers are of real interest, as must any discussion of a serious nature between intelligent and sincere men sustaining different points of view.

Mr. Harrison treats of the industrial conflict produced by the struggle between capital and labour, its fatal consequences and its possible remedies. Amongst these latter he rejects the idea of common ownership between masters and workpeople ; he rejects socialism, also exaggerated state interference, and he believes that the solution of the problem, in the railway world, lies in industrial co-operation according to a formula which he puts forward, and which consists of the proportional distribution of the gross yield between capitalists and paid workers, following rules which he lays down in the same article.

Mr. Wiener attacks the formula of Mr. Harrison with formidable arguments. The solution which he proposes is, so to speak, automatic : The just demands for increase of wages must be satisfied ; these concessions will be inevitably followed by other demands, not just, but which nevertheless the mass of railway labour will likewise get satisfied, because of the great forces at its command; as a consequence of all this, increases of rates will be necessary, against which the public will protest with growing energy ; finally, the struggle amongst all these opposing forces will result in a fair equilibrium between the profits of the shareholders, wages and tariffs, i. e. between capital, labour and the public.

Although it figures in the *Bulletin* as a sub-title, the real title of Mr. Marchand's study aforesaid is : « The administrative problems from the psychological point of view ». Mr. Marchand, in his very remarkable work, combats in a reasoned manner the solutions proposed by Mr. Harrison and by Mr. Wiener, and offers a third :

The project of Mr. Harrison — says Mr. Marchand — is correct from the mathematical point of view, but not from

the pracical point of view; it is a technical and not a psychological one... The application of M. Wiener's scheme would be, if we may use the expression, a surgical operation; before we adopt it, let use see if there is not a remedy.

Mr. Marchand sees the crux of the problem in the psychological factors ; he takes men as they are, and applies to them the treatment suggested by their own nature : adequate pay, duly increased with the years, etc., and completed by a system of premiums serving to stimulate the individual ; such is the first thing to be done. Mr. Marchand examines and rejects the system of participation in profits, in the form of a distribution amongst the staff of a portion of the surplus, as well as in that of exceptional advancement in prosperous years ; and he rejects it, amongst other reasons, as immoral, for it is not moral, he says, that the efforts of the staff should be rewarded according to the financial situation of the enterprise. Without entering into details, he goes on to establish the fundamental principles of a good premium system, embracing the higher employees. In a fashion analogous to that followed by Mr. Ambrozovics in his report to our Congress, (session of Paris, 1889), as we have noted above, Mr. Marchand calls attention to bureaucracy and centralisation, excess of which he condemns, underlining at the same time the great importance of a good administrative organisation. With regard to promotion, he considers that the best employees should be advanced, and not exactly the oldest ; and in order that the methods of selection should be just and should produce fortunate results, he details the conditions which, in his opinion, are necessary. The last paragraphs of his study constitute in part a summary and in part an exhortation. In sum, the note of Mr. Marchand is a concise work of substance and of ripe reflection.

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In the *Bulletin* for August 1920, pages 533 to 547, there is a study by the Swiss engineer Mr. R. de Vallière, entitled : « The Taylor system and some observations on its application ». After having given a synthetic survey of the said system, the author deduces its favourable consequences, which can be essentially reduced, according to Mr. de Vallière, to diminishing the cost of manufacture and distribution, which permits the increase of wages and the reduction of selling prices, and leads, in the end, to the greater well-being of mankind.

M. Peschaud, in an article inserted in the Bulletin of November 1920, pages 784 to 798, renders an account of the new status of French railway servants, and of the participation of the staff in the working of the system ; he sets forth the object of the delegations of this staff for its regional representation, its representation before the respective chiefs of service, and its representation before the Director and in the Higher Council of the railways.

Under the title : « Labour Co-partnership in transport », the *Bulletin* of April 1921, pages 456 to 459, publishes a summary of a paper read by Sir George Gibb to the last « Labour Co-partnership Congress ». The author speaks principally of the association of the staff in the management of enterprises, in which it forms part of the Boards of Directors, Committees of Management, etc., and he sets forth the advantages and drawbacks entailed thereby.

In an article published on pages 1010

to 1012 of the number for *September* 1922, under the title : « Creation of Railway Council schemes on British Railways », there is a report of what is prescribed as to this question by the new Act of 1921 dealing with the English railways, from the point of view of the participation of the staff in the said bodies.

In the number for December 1923, pages 1103 to 1105, there are summarised the essential provisions of the Ministerial order relating to the Czecho-Slovakian Railways, on the terms of which there is established, from the 1st July 1923, a system of premiums on savings in fuel and lubricating materials for the employees of the traction service.

In the number for March 1927, pages 269 and 270, there is reproduced a circular of the Canadian National Railways. By this circular, as a result of inquiries made and conferences held between masters and workmen, the system of premiums is done away with in the shops of these railways, and against this all the workmen in these shops benefit by an increase of time wages. The circular does not give detailed reasons for the measure adopted ; it simply makes an allusion to the situation created by the fusion of the lines which at present constitute the system in question, and to the utility, or rather the necessity, of unification.

IV. — The ideas and accomplishments of Mr. Ford in railway matters.

The ideas and the work of Mr. Ford in railway matters which we are now about to summarise, so far as they relate to the subject of this report, are explained in greater detail in the books which he has published, and which are worthy, in our opinion, of being attentively read and pondered.

Mr. Ford affirms that the real progress of the Ford Motor Company dates from 1914, the year in which this concern raised the minimum wage, then not much above two dollars, to the level of five dollars a day, which, he said, had as a consequence the increase of the purchasing power of the workers of the Company ; these increased in their turn the purchasing power of people outside the Company, who reacted on ever larger groups, and so on. In the view of Mr. Ford, this idea of extending the purchasing power by paying high wages and selling at low prices is one of the main bases of the present prosperity of the United States. It is, he adds, the fundamental cause of our contemporaneous society. For this reason, he gives to high wages thus considered the generic name of « wage motive ».

This conception of wages leads Mr. Ford to distinguish clearly this term : « wage motive » from two others : « subsistence wage » and « standard wage ». He says, in this connection, that high wages cannot be paid just for the asking, for if wages were raised without reducing the cost of production the purchasing power of the people would not increase ; whence he concludes that there is no wage in existence which merits the name of « subsistence wage » if it does not correspond to an equivalent amount of work. As to the « standard wage », Mr. Ford believes that there is no one in the world who possesses sufficient knowledge to fix it, and he adds that the very idea of a « standard wage » presupposes already that initiative and organisation have arrived at their limit.

Another fundamental idea of Mr. Ford's is his conception of business.

« Business », real « business », is and must be, according to him, a « public service » and nothing more ; that is, the interests of capital, labour and the consumer must be considered as fundamentally identical ; it is to be understood that if we do not proceed in accordance with this idea, we shall compromise in the end the interests not only of the workers and of the public, but also of the capitalists themselves, who will see inevitably disappearing, one after the other, the possibilities which, on the contrary, offer themselves every day in greater number and better quality to the intelligent and broad-minded industrialist.

Two main enemies of this modern conception of business are noted by the great North American industrialist, and he attacks them both with the greatest energy : *professional financiers*, and the *professional apostles of socialism*. « The two » he says « constitute a veritable menace : the professional financiers have ruined Germany : the professional social reformers have ruined Russia : which of them have accomplished the better task, one may take one's choice ».

Here are a few of his phrases :

« One may consider an enterprise as finished when it starts to make financial combinations. » « The professional reformer desires exactly the same thing as the professional financier, that is, something for nothing; and in this manner, unconsciously, financiers and reformers unite their efforts to destroy industry as an instrument of general prosperity. » « The principle of *public service* applied to business is very widespread in the United States, it will spread everywhere, and it will reconstruct the world ». « The old tricks have had their day. The old wisdom has demonstrated its foolishness. The old causes are without avail. If it is a progress to lose a false wisdom and find a new source of education, it may be said that the world has progressed. The old principles have been contradicted by experience. *Progress is not marked by a definite frontier which must be crossed, but by an attitude and an aura.* False ideas do not vanish at a given moment, nor do the true appear all at once. »

What we have just quoted suffices to make it clear that Mr. Ford is defending what at the outset of our report we called the *harmonic conception* of industrial affairs, and that in consequence he is attacking what we there designate under the names of the *classic conception* and the *socialist conception*.

* * *

Let us see now how Mr. Ford applies his general ideas to the railway world.

Some years ago the Ford Motor Company acquired by purchase the Detroit, Toledo and Ironton Railroad. According to what Mr. Ford asserts, this railway had not produced any profit before this cession ; that is to say, he explains, it had not produced any profit for the shareolders, but it had brought money in abundance to the bankers, who reorganised it from time to time. On the contrary, as soon as it was acquired by the Ford Motor Company it began to bring in to that Company a valuable interest. « But it would have produced more still for us », says Mr. Ford, « if an act of Parliament had not limited to six per cent the interest on our capital. We find ourselves limited in our service by laws designed, in part, by ill-informed theoreticians, who cannot comprehend the true function of profits, and in part

by those who see in an ordered transaction the inevitable necessity of banking finance ».

Mr. Ford then sets himself to expound in the following manner the advantages and disadvantages with which the Ford Motor Company commenced the operation of this railway. We will copy his own words :

Advantages. — 1. Complete independence of banking control. 2. A large traffic arising from the Ford Motor Company industries themselves. 3. Direct communication with all the great railway systems of the country; the old railway company had also this communication, but did not obtain the benefit of it.

Disadvantages. — 1. A completely demoralised staff. 2. The ill will of the public and of the shippers of goods. 3. A disproportioned railway, beginning nowhere and finishing nowhere. 4. A permanent way insufficient for use, and a rolling stock which was only scrap iron.

In the following chapter, Mr. Ford says :

Out of the chaos which reigned when we acquired it, we have now extracted a railway which, while only first class in its men and its administration, produced in 1925 more than two and a half million dollars, representing half of what we paid for it. This result has not been secured by a magician's wand... Even yet we have not constructed the lines we think of constructing, nor laid all the heavy section rails we are thinking of laying, nor rectified many of the heaviest gradients. We have to reconstruct the whole of the railway, but we have not yet done it. The profits have been obtained by the simple addition of a small quantity of material to what was already in service when we took over the railway, and above all by the modification of the administration. Here is what we have done :

1. Cleaned up the line and all its surroundings; 2. put all the material in good order; 3. established what we consider to be suitable wages, and exacted a corresponding output of work; 4. abolished all formalism and all division of duties; 5. acted loyally towards the public and towards those who are working for us; 6. made all the improvements with our own money.

The important point of the administration of this railway, adds Mr. Ford, is not the money which it has produced, nor whence and how it obtains its traffic. The important point is that it has thrown overboard deliberately a great mass of the old principles relative to the operation of railways, and that it is accomplishing its task with the greatest correctness at a rate much lower than the former average tariff, while at the same time paying the highest railway wages in the country. This railway is in reality more remarkable from the fact that it disdains the application of the venerated traditional formulae than from the profits that it produces.

... We did not know, for that matter, at the time of purchasing the railway, if our industrial principles would be applicable to the special railway transport industry, but we suspected they would, and in fact the reality has confirmed our supposition. Up to the present, we have not been able to do much. When we have succeeded in giving to this railway the form we wish, it may perhaps arrive at something transcendent.

... After the acquisition of the railway, the first step was to apply to it the « Ford principles » of administration. These principles are extremely simple. They can be enunciated in three propositions : 1) *to get the work done in the most direct manner without taking account of formalities or of any of the ordi-*

nary divisions of authority; 2) *to pay all the workers well — six dollars per day at least — and to ask them 48 hours work a week, but not more;* 3) *to put all the machinery into the best possible condition, maintain it always thus and insist on absolute cleanliness everywhere, in order that all may learn to respect their tools, their places and surroundings, and themselves.*

The explanations which Mr. Ford goes on to give are very curious and instructive ; he proves by facts that the rules we have just reproduced are not pure theory, welling up in the brain of some armchair thinker, but tangible and fertile realities. As it is impossible to copy all, we will limit ourselves to transcribing some significant paragraphs :

The division of labour amongst the men was done away with. Now one may see a locomotive driver cleaning an engine or a carriage, or find him at work in a repair shop. The crossing-gate keepers fulfil the office of permanent way men on all their section. The station-masters sometimes paint and repair their own stations. The guiding idea is that a group of men is deputed to make a railway work, and that one and all, if they possess good will, can accomplish that task. It a specialist has in hand a job relating to his speciality, he does it; if he has not, he does the work of a laborer, or any other work he is capable of doing... No one bothers to spy on the others, because no one is charged exclusively with that task; what governs activity is the work and not the *convenances*.

The old railway had 2 700 employees for a goods traffic amounting to 5 010 000 tons. This staff was reduced immediately to about 1 500, and today, with double the tonnage of goods, it amounts to 2 390 men, including the mechanics and employees of a large repair shop where the old engines are being reconstructed.

The railway trade unions have made no kind of objection, since all our workers get wages above the highest trade union rate. The railway menagement does not know if an employee is a union man or not; the trade unions do not appear to bother either, since the railway has been excluded from any negotiation concerning wages and from any strike order.

Cleanliness forms an integral part of our programme. The first thing we did was to clean the railway from one end to the other, and to paint all the buildings... No employee may smoke in the shops... Give a worker a good tool, an excellent and polished tool, and he will learn to take care of it. It is difficult to get good work if good tools are not used in clean surroundings. These conditions are not only important, but fundamental. They create the spirit of work. Their importance is similar to that of wages. Work will not pay wages unless conditions are established which render work possible... Stations and platforms must be swept at least three times a day... The locomotives and all the machines in the repair shop are polished up like a new motor car. The vans are kept clean and comfortable; often brakesmen enter them before working hours to scrub the floor. It is said that an employee of the Detroit, Toledo and Tronton Railroad always carries in his hand a handful of cotton waste for cleaning. It is the insignia of this railway! But, once used, the cotton is not thrown away, but goes to a factory which cleans it and makes it like new. No rag is thrown away. Everything passes through our renewing plant.

... The train chief of one of the most important branches of our railway had commenced to work as a platelayer when he was 16 years old. He earned 10 cents an hour, and often got noth-

ing for three months. His father was inspector of the same section, along with three other inspectors and a numerous gang. Today this train chief is in charge of the whole branch, and there are no inspectors. In their place, we have some additional permanent way men who act on their own initiative, instead of being directed from above. When the new plan was put in force, this train chief said to the permanent way men : « Wouldn't you rather, boys, drive in a spike or lay a sleeper where you think it's wanted, than walk along and wait till I come and tell you to do it? »...

... Any workman can go direct to the central service, and everybody knows it. The cause of derailments is a delicate question on all railways, and with the old methods the track men were always at fault. At present, they have facilities for being heard, and we can determine the real culprits, who are rarely the track men...

... The absence of rules, far from being a disadvantage, is useful to us in many ways. Here, for example, is what the chief of a locomotive depot, who has had 30 years service with the railway and is 68 years of age, said on a certain occasion : « Sometimes I have to shift a wagon and have no engine at the depôt. In the old days, if I had asked a regular engine and crew to move this car, they would have told me to do it myself, because shunting wagons was not in their contract. Today, any engine available will shift the wagon ». We pay our men to work, and not to discuss regulations.

... The workman who earns the least on our little line gets 1 872 dollars a year for 2 496 hours work. According to the statistics of the « Interstate Commerce Commission », the average pay of the employees on railways of the first class, not including officials, was, in 1923, 1 588 dollars per year of 2 584 working hours — that is, the employees of the Detroit, Toledo and Ironton Railway who get the smallest wages earn 25 dollars a year more than the average wage on the first class lines...

We have, further, established on our railway, for the workpeople, a system of investment. The desire to invest money is a right one, and a legitimate reason for censure of our civilisation resides in the fact that a man cannot invest his savings in the industry in which he works; he would obtain from that fact an extra income, and his devotion to his employer would be greater. If there were more possibilities of making safe industrial investments in businesses with which the public is familiar, the fraudulent financial projects so much exploited would have less success. Our system has been working since October 1923; up till now, the employees have subscribed for bonds amounting to 600 000 dollars, and the subscribers represent more than one half of the staff. They pay for these bonds with their wages, and we permit them to buy up to a quantity not exceeding in amount one third of their wages. No interest is guaranteed to them, but they are paid 6 % if they require to withdraw the funds invested. It is essentially a profit-sharing system in conformity with the law and with the railway regulations.

... In 1920, under the old enterprise, the operation coefficient of our railway was 125.4 %; in the first year it was under our direction, and practically with the same material, it was brought down to 83.8 %. At present, it is 60 %, i. e. lower than the average proportion secured by the best equipped railways in the whole country...

... This experiment, concludes Mr. Ford, is not lacking in importance. For long the railways of our country have lived in a state of war with their employees, or with the public, and sometimes with both. The struggle has been so prolonged that the primary object of

the railways appears to have been forgotten. I have faith in the efficacy of private ownership. Under the regime of private ownership, it is possible to manage any business in such a way as to pay high wages and to ensure cheap service (1).

To conclude the indications we have just given of the views and work of Mr. Ford in railway matters, we will advise the reading of an article in the « Railway Review », which has been reproduced in the January 1924 number, pages 77 to 80 of the *Bulletin* of our Association, under the title : « The Ford plan of staff participation ». It treats of the authorisation which Mr. Ford asked for from the Interstate Commerce Commission, to apply on the Detroit, Toledo and Ironton Railroad the profit-sharing system which the Ford Motor Company had in force for some years, and which consists of the issue of special variable-interest debentures in favour of the staff. This is a question to which we have already made allusion above, by reproducing some words of Mr. Ford's concerning the investment of money by employees in the actual concern they serve. The *Bulletin* article terminates with an extract from the report of the Interstate Commerce Commission. For our purpose, it will suffice to copy here the last paragraph of this document, which is very eloquent, in view of the immense authority of the organisation whose signature it bears :

« The plan in question in an experiment, but it is only by the experimental method that we can try out what is new. Perhaps there is at the present moment no question more important for the public than that of the relationship between master and paid workers. The domain of railway operation is vast, and the opportunities of improving personal relations are unlimited. Any attempt to the realisation of this desideratum must be received favourably. The world knows the actual author of this plan as an industrial genius. It may be that this man will succeed in creating in the domain of transport something as sensational as certain of the innovations he has introduced in the domain of industry. Our duty is to encourage the proposed experiment, and to give it our sanction so far as we are authorised to do so. »

V. — Before and after the European War.

Before the summer of 1914, no one suspected that the next war was to break out so rapidly, and still less that its development and consequences would have the enormous influence they have had on the march of humanity, such an influence that some declare that this war will be treated in history as the line of demarcation, not between two epochs, but between two eras. Then many thinkers, amongst them some really great men, were already applying the main energies of their talent and activity to the solution of social problems, and, more concretely, of all the problems raised by the growing struggle between employers, workers and consumers, i. e. between capital, labour and the public.

Before the war, the eminent Taylor had already devoted twenty-six years of tenacious efforts to the execution of his 45 000 tests, having as their *apparent* object the determination of the laws by which manual labour can give, for equal effort, the maximum output. We say

(1) These quotations are taken from the Spanish edition of Mr. Ford's work : « To-day and to-morrow.

apparent, because the real object or at least the result obtained by Taylor did not consist of solving this problem in its purely theoretical aspect, but has had a much greater importance.

An authority on the subject thus summarises the results of the gigantic work of Taylor :

In sum, what deductions does Taylor draw from a lifetime of observations, detailed study and sustained effort?

a) To perform even a simple task, to load sand, for example, there are a hundred different methods of procedure — *one of these methods costs less effort than the others.*

Then it has to be perfected.

b) The scientific study of the loading of sand MUST be carried out by educated men. The same is the case with ALL industrial processes, in the study of which *there are no negligible details.*

Taylor thus enlarged, without limit, the duties of chiefs.

c) The purpose of Taylor is the economy of human effort applied to industry. It is absurd to make useless efforts. All the wealth of a civilisation springs from the efforts of men.

d) By scientific organisation of work, men will be able to produce *much more wealth* than today, with less effort. To this end, *it is necessary to impose upon them scientific methods.*

e) The abundance of wealth will increase the purchasing power of wages; with the increase of material wealth, there will be an increase of general well-being.

f) We must avoid charging a man with a task for wich be has no aptitude, or but little.

g) In the application of the system, it is necessary to be prudent, tenacious, industrious, humane and psychological.

And the same author summarises in brief words as follows the capital and transcendent conception of Taylor, identical with that of Ford :

Taylor shows how the capitalist, the employer, the workman and the public have an identical interest in the increase of wealth to be obtained under the direction of chiefs, clever psychologists, attentive, tenacious and industrious observers.

We have borrowed the preceding lines from a book entitled : « Le socialisme et l'art de commander dans l'industrie » (« Socialism and the art of command in industry »). This book was written at Liége in February 1914, i. e. months before the outbreak of the great war. Its author, the engineer, Mr. Henry, is not a dreamer ; he is a professional, a practical man, but, at the same time, a thinker endowed with much general culture. We transcribe below some of the passages which conclude his work :

When it is a question of improving the relations between employers and employed, a problem of infinite complications, we remain confounded by the assurance with which men who pass for learned men discuss the main lines of this colossal study.

In their genial brains, they group the workers of the future in admirable collective associations, of which they outline the general structure, with a certainty of touch only permitted them by their profound ignorance of details.

Here, the detail is the man himself; every honest man who sells his services is worth studying; let us do it sincerely, with a desire to arrive with him at a lasting agreement.

The worker who discusses the value of his personal work elevates himself; let us then put him in a position to do so, *and do not let us oblige him to sell mediocre work for a mediocre wage, to a collective group — which is a veritable return to barbarism...*

In large-scale industry, the worker, to defend his rights and the value of his work, must address himself either to the trade union organisation or to the employers' organisation. He has no other choice.

The former must be already far advanced towards such perfection as is possible, since its groups include millions of adherents, and these, by universal suffrage « can choose the best chiefs... » These eminent persons, of whom many are very aristocratic, very refined, very... decadent, make numerous speeches, publish very large books, very difficult to read, where there is repeated hundreds of times the same ode to the Sovereign People; they profess to lead millions of workers, and up to the present have only been able to group them to *defend rights* and to prepare a strike or an agitation, but *never to obtain the most economical production.*

The second, the employers' organisation, has proved itself; it is remarkably productive. But, *in its treatment of the worker, it remains often despotic, empiric or rudimentary.*

The vast problem still interests too small a number of cultured men.

When, in the great factory, a motor of a few horse-power gets overheated, an engineer sees to it immediately, makes tests, takes measures to prevent the recurrence of this minor technical accident. If the phenomenon is repeated, the scientific investigations are resumed, concern is felt, with reason, regarding the surroundings in which the motor is working; thermometer, hygrometer, acidity of air; the demands made on the machine, both mechanical and electrical, are examined; the various parts are dismantled, examined, submitted to multiple tests — in brief, nothing is neglected to ensure the service of this little auxiliary! If necessary, a specialist is consulted, accustomed to researches of this kind.

And when a workman gives notice to leave, it is unlikely that anyone will trouble about his motives for going; an inquiry of a somewhat methodical nature into the demands made on this little human auxiliary is practically never made.

How has he been working? Since when? Is he well or ill controlled? What is his age, his diet, his dwelling, his family, his needs, his wage, his industriousness, his state of health? What are his aptitudes, the services he has rendered, those which he may still render? What are all the « details » which may have had influence on the decision, made by this workman, to leave the factory?

These are questions which are hardly ever asked about the *human motor*, and yet their study, and their study *alone*, can permit of the constitution and maintenance of a population of workers, sane, stable, well paid, having a large output and living in peace!

Outside of this difficult study, made up of a thousand details, full of science, good sense, patience, equity and enthousiasm, there exists only vain and conceited rhetoric!

But, the sceptics will say, can we find a sufficient number of men prepared to approach the solution of so fast a problem? *Obviously, this is the most serious objection which can be made to our point of view!*

Now it is always necessity which creates the function and the urgency of the measures to be taken cannot be doubted by anyone. The army of engineers, lawyers, doctors and men of culture who hold themselves apart from industrial realities is large enough already for the employers' side to draw therefrom the aids which it requires, immediately, and to be able to make the necessary sacrifices to ensure their *scientific* collaboration.

It is time indeed that an army of edu-

cated and experienced men should commence to probe into all these ill-designed schemes which are presented to us with impunity in the form of general solutions, applicable equally to everybody; schemes of which the theoretical success is only due to the greatness of the illusions they create.

What an admirable thing, is it not, *Monsieur le Député*, this new invention calling itself *the interest of the worker in the general profit of an enterprise?*

In what agreeable idleness may henceforth repose the master who finds it sufficient, to reward the workers, to refer to an accountant at the end of the year! A simple sum in rule of three, every twelve months, will permit each one to be remunerated for his initiative and his personal merits !...

* * *

The examples we have just cited will suffice to show that before the European war many thinkers, and amongst them some eminent ones, who were also men of action, and of intense activity, useful and fecund, believed the moment had arrived for a radical transformation of the rules prevailing in modern industry, to increase and extend its *output* and its *profits*. But we think we should seize this opportunity to recall to mind once more, with the praise he merits, our predecessor in the charge which, not through our own merit, but through the kindness of the Permanent Commission of the Congress, we have today the honour to fulfil — Mr. Ambrozovics, who, forty-one years ago, expressed himself in terms of which we have given an idea above.

And, what a coincidence ! If Mr. Henry had known the cold reception, disdainful in fact, which the 4th Section of our Congress gave to Mr. Ambrozovics in 1889, he would perhaps not have written to explain it phrases other than the following, likewise contained in his work :

If one were to seek amongst the corps teaching in our higher technical institutes what number of professors had had the opportunity of working in industry and of leading men therein *with success*, it would be found that *the number approached zero.*

Certainly, it is necessary to have savants, investigators and theorists to form engineers, but is it not at least regrettable that these young people can rarely or never meet at the technical schools *masters who teach them that they will have to lead men?* Masters who can convey this teaching, *apart from dogmas and political beliefs*, and with the authority which personal experience alone can confer.

Masters who will explain how to acquire the prestige necessary for control, also the harmony and discipline indispensable for the *economic production* of goods.

Masters who will show the amplitude of the role which future employers will have to fill, the extent and importance of the wealth which they will have to divide between labour (wages), capital (interest), and the State (taxes).

Masters who, after having inspired love and admiration for the marvels realised by order, method and scientific experiment applied to matter, will awaken understanding of all that may be expected from the same processes applied to the physiological and psychological study of the human machine !...

If those who *thought* before 1914 thought thus, it is not surprising that those address themselves today to similar reflections who, since 1918, have commenced to *think*, and even the great majority of the immense multitude of technicians, industrialists, business men,

professors etc., who are not in the habit of exercising their mental activity in the interests of the community, but *live from day to day*, march with the crowd — in a word, conduct themselves according to the standards taught by routine, learned and practised by routine. It is not surprising, we repeat, that in the present critical times ideas and methods are opening up a path for themselves which in 1889 appeared wrong and perhaps Utopian. It is not surprising that, in all the professions, we see momentarily increasing the number of cultured persons to whom psychology and sociology no longer appear extravagant things, subjects for poetry or recreation, but *sciences* which, while still in their infancy, have already the rank and merit the name of sciences into which those must be initiated who occupy in industry a more or less important directive post, with the same attention and the same zeal as they devote to the study of technical and commercial questions.

But although these ideas have begun to become common, it is well that we should not tire of repeating, so as to combat the defenders and practitioners of the Roman *jus abutendi*, and also the charlatans who deceive the masses, that Science and Science alone can supply effective and decisive means to solve the most complex social problems raised by modern life, and in concrete terms, in order that Capital, Labour and the Public may be transformed from bloodthirsty enemies into cordial collaborators.

« Under various names », says Gustave Le Bon, « men in all ages have really adored only one divinity - Hope ».

It is proper, let us add, that the rich should hope to be richer, the poor that they may cease to be poor ; but poor or rich, let us all also place our hope in Science, who, on the sole condition that we listen to her and follow her counsels, is the sole power capable of transforming, so far as is possible, our gilded human illusions into tangible realities.

VI. — **Our detailed questionnaire and replies received.**

Free from all prejudice, from all passion, from all personal interest, whether of class, enterprise or corporation ; desirous of only letting ourselves be guided by the light of Science, but of *complete* science, of science understood as we have just explained ; inspired, consequently, by the reflections made above, and having duly collected documentary information, we had to draw up a plan or draft of a detailed questionnaire relative to Question XV.

We divided this questionnaire into three parts : the first concerns the general systems and the *special* measures adopted to incite the staff *directly* (as individuals or small groups) to co-operate with the Administrations for the improvement of output and the increase of profits (premiums, bonuses, exceptional promotion, various rewards, facilities for acquiring shares and debentures). The second part relates to measures of all kinds (general operating organisation of the undertaking ; wages ; relations between railway staffs and administrations, including, should occasion arise, the representation of the former on the Boards of Directors, etc., recruiting ; employers' organisations, etc., etc.), already taken with a view to inciting indirectly the whole of the workpeople to colloborate in the increase of output and the increase of profits. The third part is devoted to the *measures contemplated for the future, and above all to the fun-*

damental conceptions of the management of each railway system with regard to the basis of Question XV of the Congress of Madrid, to the measures which will be taken as a result either of their own railway experience or of the study of the theories elaborated and experiments made by all sorts of persons, entities and industrial undertakings, whether connected with railways or not.

By reason of their special interests, we think it advisable to reproduce here the following paragraphs of the Questionnaire :

The reply to the 2nd part will be reduced to a very brief sumarry, intended in the main to make known the opinion of the management on the importance of the *indirect* measures indicated above, from the point of view of their effect on the participation of the staff in the revenue and profits of the railway, not merely applying these two terms, revenue and profit, to matters concerning the interest on the capital involved, but also regarding the railway industry as a « business », this word being used in the sense indicated in the definition of the contents of this part of the questionnaire.

In the 3rd part, there should be specially notified the view of the management on the present theories and tendency of the modern, *soi-disant* more intelligent capitalism, based on the devoted *co-operation* of the staff, high wages, very hard work preferably for a short day, and *simultaneously* on the reduction of the cost price, of which the essential idea is the new conception of the word « business » as a « public service », in which the interests of capital, labour and the public are essentially one, and of which the most striking application in the railway domain has been, for some years past on trial on the Detroit, Toledo & Ironton Railroad acquired by the Ford Motor Company, and to which Mr. Henry Ford has extended his general and well known methods of industrial operation. What the Interstate Commerce Commission has said in this regard, in an official document, should be noted : « It may be that this man will succeed in creating, in the domain of transport, something as sensational as certain innovations he has introduced into the domain of industry. »

The reply to this 3rd part should be, needless to say, as matter-of-fact and as little literary as the others, but we would like the Administrations to understand that we consider this part as the most important of the three which make up the questionnaire, and perhaps the most outstanding of the Madrid Congress, in the sense that the replies made to this part 3, the discussion and the conclusions of Congress in this regard may mark with a definite imprint — in our humble opinion — the physiognomy of the social, financial, organic and administrative mentality of those who direct the railways of almost all modern nations. For this reason we — least of all — feel able to define limits of any kind to a reply to this question.

The draft of the questionnaire once drawn up, and obeying with the greatest pleasure the reiterated indications which the Permanent Commission of the Congress has at all times given to reporters, we had the honour of addressing ourselves in the first place to our distinguished French colleagues, Messrs Soulez and Bloch (the American reporter, Mr. Cook, was nominated a long time afterwards), with whom we had later a long conference in Paris.

As a result of the conversations held there, the first part of our questionnaire was left definitely drawn up in a manner very similar, identical fundamental-

ly, to the questionnaire drawn up by Messrs Soulez and Bloch.

These two gentlemen welcomed with every sympathy the second and third parts of our questionnaire. However, they did not incorporate them in theirs, because as they pointed out, they were perfectly familiar with the ideas professed on this subjects and with the methods adopted or envisaged for the future by the railway administrations of France and Belgium, the only two countries which had been assigned to them as reporters.

Finally, the questionnaire was accepted by the Permanent Commission, who had it printed and sent to the respective Administrations.

Appendix No. 1 is a copy of this questionnaire, which we reproduce in full in order to make its spirit known to the reader. It may be, indeed, that those who only read the questionnaire may not succeed in interpreting accurately our ideas and our aim. At least, this is what happened with the majority of the Administrations assigned to us by the Permanent Commission of the Congress, as we are going to explain later on.

Appendix No. 2 is a list of the Administrations who replied to the questionnaire. Comparing this list with that of the Administrations assigned to us, the relatively small number of replies will be noted.

It is well to state, moreover, that, amongst all the replies received, the majority content themselves either with simply acknowledging receipt, or with giving a few very brief particulars (sometimes none, because the undertakings in question have not established any staff participation scheme) which we are unable to use, or with communicating more or less numerous data and figures which did not however in any way solve the problem enunciated in the questionnaire.

It is for this reason that we said above that the majority of the Administrations has not properly interpreted our ideas, our design. And we will add that different Administrations, more or less indirectly, some in extremely clear terms, have given us to understand that in their opinion our questionnaire is *Utopian*. These manifestations of opinion, as all those made in sincerity, must be received with gratitude, and are so by us, the more so that our sole ambition is to contribute to the discovery of truths useful to society in general and to the railways in particular, and in view of our conviction that none, least of all ourselves, can have the right to be considered infallible.

In view of what we have just set forth, we can only recommend to the Permanent Commission, for total or partial publication in the Bulletin, the replies received from three Administrations.

In the first place, we publish in its entirety (as Appendix No. 3), the reply of the Swiss Federal Railways, but naturally without the voluminous and very complete appendices which this Administration has had the kindness and the judicious initiative to add to its report.

Appendices 4 and 5 are extracts from the replies supplied respectively by the Czecho-Slovakian State Railways and the Bulgarian State Railways and Ports.

Perhaps we might also give in an appendix some extracts from other replies received, but we think they would throw no new light on the question.

The reason which has decided us to publish integrally the reply of the Swiss Federal Railways is that this reply conforms with greater approximation than any other to the indications given in our

questionnaire, *this being considered as a whole*.

The reply of the Czecho-Slovakian State Railways begins in these terms :

Generally, it is appropriate to draw attention to the fact that the questionnaire has reached the Administration at the time when works relating to the majority of the subjects of the different questions are under consideration. The Czecho-Slovakian Republic, inasmuch as it formed part territorially of the old Austro-Hungarian Monarchy, was constrained, at the time of its constitution at the close of the World War, to take over an economy completely overthrown by the general devastation of productive forces and by the demoralisation of that period.

Notwithstading this modest declaration by the Czecho-Slovakian State Railways, we think we ought to reproduce the whole of the third part of their reply, in which, under the sub-titles : « Essence of Question XV », « Measures contemplated for the future » and « Idea of modern capitalism, said to be the most rational », they set forth a study worthy, in our idea, of being known and taken into consideration by the 4th section.

Finally, we reproduce the last paragraph of the second part and all the third part of the reply of the Bulgarian State Railways and Ports, by reason of the important declarations made therein.

VII. — Conclusions.

« Progress is not marked by a definite frontier which has to be crossed, but by *an attitude and an aura.* » These words of authority, transcribed above, return to the memory by a spontaneous concatenation of ideas, at the difficult moment of our being obliged to formulate our proposition to the 4th Section, just because it is precisely an attitude and an aura which, to judge from most of the replies received, one does not meet with in the *whole* body of railway administrations.

We have always believed that the associations which are so numerous in our times, from the League of Nations to the most modest societies, taking in on the way our International Railway Congress Association, composed of representative personalities, intelligent and animated with good will, meeting periodically, not to give orders which they have not the means to impose, but only for the purpose of stimulating initiatives and activities — we have always believed, we say, that associations of this kind have, above all, a primary mission to fulfil : *to adopt an attitude, to create an aura.*

Without doubt, the technical railway questions, relating to the track, to traction etc., are extremely interesting ; it is interesting also, to revert to our theme, to compare Administration with Administration, the number of francs received by each engine driver for a certain number of tons of coal saved during running, the annual bonuses granted to the staffs of the undertakings, etc., but certainly it is not these isolated points of view, unconnected, with limited horizon, which are the most important when it is a question of studying a problem having the gravity and breadth of that concerning the « Co-operation of the staff towards increased efficiency and its participation in the profits ». An Association such as ours has been created for something greater and more important. « Noblesse oblige », the adage says. If isolated individuals, however eminent, are only individuals ; if Taylor and Ford and others of their stature study the problems and details of industry, ap-

parently insignificant, with so much ardour and profundity, an Association of the standing of ours is much more obliged to follow the same line of conduct. If the main characteristic of great intelligences is to know how to raise the ordinary pettinesses of life to the plane of general ideas *whence, and whence only, one may presume to control men with success*, with how much more reason should a corporation like the International Railway Congress Association aspire to live on that high plane !

Let us return to our original idea. If we say, for example : « Premium received by traction staff for economies realised in fuel and other material », it is incontestable that this question must be in part the object of a study by the second section. In a similar way, it is to the first and to the third sections that it pertains to examine all the questions of the same kind relative to the corresponding services. But if we say : Co-operation of the staff towards increased efficiency and its participation in the profits » then there are two alternatives — either the question must be split up into three parts, assigned respectively to the 1st, 2nd and 3rd sections, each specialising in its own branch, the 4th section confining itself to combining and harmonising in one whole the partial conclusions of the three others, or else the problem must be studied exclusively by the 4th section, as has been decided in the present case, and, this granted, it is our opinion, seeing the age in which we live, that it can only be contemplated with great breadth of vision.

To conclude, we have the honour to propose to the 4th Section of the Congress :

1. That the deliberations of the Madrid Session on the question « Cooperation of the staff towards increased efficiency and its participation in the profits » should have as its object the examination of the question from the elevated point of view which, in our opinion and in conformotiy with what we have explained, is the one really appropriate ;

2. That if the 4th Section considers that the preliminary study of Question XV is not sufficiently ripe for its deliberations to have the full effect desirable, as it did in the session of Milan 1887 for its question XXI, the same subject should be included anew in the questionnaire of the next session of the Congsess, as it was decided then. It may be that there would be today better and stronger reasons for proceeding thus, seeing that the movement of modern ideas in the matter in question is much wider, more intense and more accelerated than at that time.

3. Finally, that if the 4th section finds the above proposition justified, it shall consent to devote a part of its meetings in the session of the Madrid Congress to the more adequate drawing up of the detailed and uniform questionnaire which, under the same title : « Co-operation of the staff towards increased efficiency and its participation in the profits », should be addressed to all the Administrations forming part of the International Railway Congress Association, with the invitation to send their replies to the reporters to be designated, to the number of three or more, as now, to facilitate the work — the respective statements of which would form a basis for discussion in the next session of the Congress.

Madrid, 30 July 1929.

APPENDIX I.

Detailed Questionnaire relative to Question XV.

I. — Composition of the Questionnaire.

FIRST PART.

General systems and special measures adopted with a view to inciting the staff *directly* (individually or in small groups) to assist in the increase and improvement of revenue and profits.

a) Premiums;

b) Bonuses;

c) Special promotions;

d) Various (honorific rewards, various permissions, facilities and measures of every kind, with a view to rendering work less arduous to this or that group of railway servants, etc.);

e) Facilities for the acquisition of railway stock.

SECOND PART.

Measures of all kinds (general organisation of the operation of the undertaking; wages; relations between staff and railway administrations, including, where occasion arises, the representation of the former on the Boards of Directors, etc.; recruiting; employers' organisations, etc., etc.) with a view to inciting *indirectly* the whole of the railway servants to assist in the increase and improvement of output and profits.

THIRD PART.

As a result, either of the experience acquired by the system (1st and 2nd parts), or of the study of the theories and experiments elaborated or made in other industrial operations, even extraneous to railways, to set forth the measures contemplated for the future and — above all — the fundamental ideas of the directors of the system on the basis of the XVth Question of the Congress of Madrid.

In the third part, to give specially the opinion of the Directorate on the present theories and tendencies of the modern, *soi-disant* more intelligent capitalism, based on the devoted co-operation of the staff, high wages, harder work but during a shorter day, and (*simultaneously*) on a reduction of costs, of which the essential idea is the new conception of the word « business » as « public service », in which the interests of capital, labour and the public are essentially one, and of which perhaps the most striking application to railways has been under trial for some years on the Detroit, Toledo and Ironton Railroad, acquired by the Ford Motor Company, and to which Mr. Henry Ford has extended his well-known general method of industrial operation. It should be noted what the Interstate Commerce Commission has said, in this regard, in an official document : « It may be that this man will succeed in creating, in the domain of transport, something as sensational as certain of the innovations he has introduced into the domain of industry. ».

II. — Difference between « premiums » and « bonuses ».

To avoid confusion and loss of time, we remind the administrations of the following words of the president of the 4th Section of the Paris Congress, 1889 (Mr. Noblemaire). « In the interests of the discussion, I think it well to define the difference which I make between *premiums* and *bonuses.* We should agree only to employ the former word when it is a question of *a predetermined*

share in the saving realised, and to call allowances or bonuses *all the other sums going to swell the wages of the railway servants.* » (*Bulletin of the Railway Congress*, August 1890, p. 1057 (French edition).

Such is the latest official doctrine of our Association, to which we ask for adherence in the replies to the questionnaire, it being understood that the phrase : « when it is a question of a predetermined share in the saving realised » means : a share capable of being calculated, and in fact calculated, in advance, as a function of the economies or of the profits realised.

III. — Form in which the replies to the questionnaire should be formulated.

Replies to the 1st Part.

The administrations consulted are asked to be good enough to adopt for their replies, as regards this part of the questionnaire, the classification by services and by articles detailed below, in order to facilitate our future work of compilation.

However, if any circumstance leads certain undertakings to change this arrangement, we should be much obliged to them if they would send us in the form which suits them best all the corresponding information which might interest us, enclosing the service documents regulating the premiums, bonuses, sharing schemes, etc. established.

After the description of each of the general systems and special measures adopted, in a synthetic but complete manner, the results obtained, should be indicated in a manner inspired, if possible, by the spirit of the remarkable and really praiseworthy note which may be found in the *Bulletin of the Railway Congress* for February 1889, pp. 59 to 69 (French edition) ; the statement should be finished by a documentary summary for the whole of the system, in which, embracing in one survey the general systems and special measures adopted, there will be spoken of the evolution in the past of the said systems and measures, and an attempt will be made to show the present situation, in all its bearings, particularly by giving figures : of the total sum expended by the administration in premiums and bonuses: of the total number of employees benefiting by these, with the proportion per cent of the total effectives; of the average increase of individual remuneration: of the advantages obtained by the railway system and of the amount of the economies realised and due to these systems and measures.

FIRST SECTION.

Systems adopted to interest the staff in the revenue.

1st Question. — What are the :

Premiums, bonuses, special promotions, various rewards and facilities, having as their object to stimulate the discernment, devotion, initiative, vigilance and, in general, the personal merit of all the lower grades of the system, from the general point of view, i. e. apart from the special nature of their service — the general systems and special measures relating to which will form the subject of the 3rd, 5th, 6th, 7th and 8th questions.

1. To reward the authors of new methods proposed and adopted with a view to increasing or improving output;

2. To reward the discovery in good time of damage, disturbances of loads and irregularities of all kinds, which may lead to the avoidance of accidents or simply to pecuniary economies;

3. To reward the supervision of the properties of the company, the prevention of malicious acts, fraud, etc.;

4. To reward various kinds of economies, such as : fuel allotted for the heating of stations, shops and buildings in general; products serving for the lighting of the same premises; cleaning articles and utensils, etc.;

5. To reward any other sort of merit of the lower grades in general.

2nd QUESTION. — What are the :

Premiums, bonuses, special promotions, rewards and various facilities specially reserved for the middle grades (gangers, foremen, workshop managers, depot foremen, maintenance foremen, etc.) by reason of their merit and above all in view of the good management of their establishment.

Define the rewards corresponding exclusively to the management of these middle grade employees, and the measures taken to reward the lower staff under their orders, indicating the question in which these measures are described.

3rd QUESTION. — What are the :

Premiums, bonuses, special promotions, rewards, and various facilities specially reserved for the junior and middle grades employees of the headquarters administration, headquarters of divisional departmental services, and outside establishments where there is office work (drawing offices, copying, typing, filing, checking offices, cashiers' departments, share department, etc.).

4th QUESTION. — What are the :

Premiums, bonuses, special promotions, rewards and various facilities specially reserved for the higher grade employees of the headquarters administration and of the headquarters of divisional departmental services.

5th QUESTION. — What are the :

Premiums and bonuses concerning specially the junior grades of the operating service :

1. Premiums and bonuses, duly classified, granted to the employees responsible for the control of passengers in the trains and stations, based on the discovery of irregularities in connection with passengers (extra charges, proceedings for contravention of bye-laws, etc.);

2. Premiums and bonuses granted to employees charged, in the stations, with classification operations in connection with goods transported (luggage, postal parcels, fast and slow goods) on departure or arrival, particularly as regards verification of weight and nature of goods;

3. Premiums and bonuses granted to labourers (tonnage premiums);

4. Premiums and bonuses for the staff charged with office work, such as ticket distribution, etc.;

5. Premiums and bonuses for employees working points and signals;

6. Premiums and bonuses for the shunting staff (including brakesmen and movement office men);

7. Premiums and bonuses for lamp-room men;

8. Premiums and bonuses for train staffs (head guards, guards, inspectors, shunters).

9. Premiums and bonuses for other special agents of the railway operating service.

If some of these premiums are also applied without descrimination to middle or upper grade employees, dealt with under other questions, this should be indicated here, with explanations of the case, as regards the general system adopted, as in those other questions for the precise steps taken relative to the said middle or upper grade employees.

6th QUESTION. — What are the :

Premiums and bonuses granted in par-

ticular to the junior grades in the rolling stock and traction service :

1. Premiums and bonuses, duly classified, attributed to employees charged with the driving of steam or electric locomotives, for savings in coal, current and oil, or for the work done — quantitatively (mileage run, load hauled) — or qualitatively (mileage run between two returns of the locomotive to the shops, number of infractions of rules, failures, delays, damage, time made up or lost in running, careful maintenance of engine);

2. Premiums and bonuses adopted for the train examination staff (on departure, arrival and *en route*), in proportion to the number of trains or vehicles examined, and the number of defects discovered or repaired;

3. Premiums and bonuses for the shunting staff, also for the rest of the artisans and their mates in the various establishments (depots, maintenance, shops, stores, yards, coal parks, etc.);

4. Premiums and bonuses for other special employees of the rolling stock and traction service.

If any of these premiums apply also without discrimination to middle and upper grade employees, dealt with under other questions, state this here, giving explanations of the case, with regard to the general system adopted, as in those other questions for the precise steps taken with regard to the said middle and upper grade employees.

7th Question. — What are the :

Premiums and bonuses concerning specially the junior servants of the permanent way and works service :

The premiums and bonuses, duly classified, which can be attributed to the minor servants of all grades in the permanent way and works service shall be posted up, it being understood that the criterion of the utility of the introduction of the premium system into this service, formerly altogether negative, has now been in full evolution for some years (see e. g. the article published in the *Bulletin of the Railway Congress*, January 1898, pp. 3 to 18).

If some of these premiums apply also without discrimination to middle and upper grade staff, dealt with under other questions, state this here, giving explanations of the case, as regards the general system adopted, as in those other questions, for the special steps taken relative to the said middle or upper grades.

8th Question. — What are the :

Premiums, bonuses, rewards and various facilities alloted to the junior servants of the various services :

1. *Temporary staff and contractors employed on the System.*

Should the Railway Company use auxiliary staff, either directly or through the medium of contractors or companies, for certain work; labouring, cleaning, disinfection, repair of rolling stock, of fixed plant, buildings or track, office work, etc.) and if, in this case, the output of work appears in the calculation of the remuneration paid by the System, there should be classified and entered the premiums, bonuses, rewards and various facilities, in the same way as for the servants of the System.

2. — *Special cases.*

For special cases, one should proceed according to the particular conditions in which such present themselves.

SECOND SECTION.

Systems adopted to interest the staff in the earnings.

Only Question. — What are the :

Premiums, bonuses and facilities for the acquisition of stock, which may be

established as a function of the profits obtained by the Railway System.

1. Premiums and bonuses granted in relation to profits, either as a function of the gross receipts, net receipts or dividend, etc.).

2. Facilities accorded by the Administration for the acquisition of stock for the employees of the undertaking : shares, debentures, special bonds.

Reply to the 2nd Part.

The reply to the second part will be reduced to a built up note, intended mainly to make known the opinion of the Directorate on the importance of the *indirect* measures indicated above, from the point of view or their effect on the participation of the staff in the revenue and profits of the railway, not only applying these two terms : revenue and profit, to what concerns interest on the capital involved, but also envisaging the railway industry as a *business*, this word being used in the sense indicated in the definition of the contents of the 3rd part of the questionnaire.

Reply to the 3rd Part.

The reply to this 3rd part must be, needless to say, as substantial and as little literary as the others; but we should like the Administrations to understand that we consider this part the most important of the three which compose this questionnaire, and perhaps the most outstanding of the Madrid Congress, in the sense that the replies made to this 3rd part, the discussion and the conclusions of the Congress in this regard, may mark with a definite imprint — in our humble opinion — the physiognomy of the social, financial, organic and administrative mentality of the railway directors of nearly all modern nations. For this reason we — less than anyone — would care to define limits of any kind to the reply in question.

APPENDIX 2.

List of administrations who have replied to the detailed questionnaire.

COUNTRY.	Length of lines.		Administrations.
	Kilometres.	Miles.	Designation.
Bulgaria	2 285	1 420	State Railways.
Denmark	2 458	1 527	State Railways.
Spain	1 644	1 022	Andalusian Railways.
Do.	201	125	Catalan Railways.
Do	302	188	Central Aragon Railways.
Do.	777	483	Madrid to Cacérès, Portugal and West of Spain Railways.
Do.	3 670	2 280	Madrid to Saragossa & Alicante Railways.
Do.	297	185	Medina del Campo to Zamora and Orense to Vigo Railways.
Do.	3 692	2 294	North of Spain Railways.
Greece	1 320	820	State Railways.
Italy	296	184	Mediterranean Railways.
Do.	76	47	Turin Tramway and Light Railway Company.
Luxemburg	207	129	Guillaume-Luxembourg Railways.
Do.	250	155	Prince Henri Railways and Mines.
Norway	3 307	2 055	State Railways.
Holland	2 169	1 348	Netherlands State Railway Company.
Do.	1 458	906	Dutch State Railway Company.
Do. (Colonies)	863	536	Dutch Indies Railways.
Do. do.	388	241	Semarang-Cheribon Steam Tramway.
Poland	16 993	10 559	State Railways.
Portugal	185	115	Portuguese National Railway Company.
Do. (Colonies)	1 049	652	State Railways.
Yougoslavia	9 004	5 595	State Railways.
Sweden	6 055	3 762	State Railways.
Do.	261	162	Göteborg-Boras and Boras-Alfvesta.
Do.	238	148	Stockholm-Roslag.
Do.	479	298	Stockholm-Vesteras-Bergslagen.
Do.	92	57	Uddevalla-Venersborg-Herrljunga.
Do.	380	174	Västergötland-Göteborg.
Switzerland	2 942	1 828	Federal Railways.
Do.	253	157	Bernese Alps Railways.
Do.	276	171	Rhætian Railway.
Do.	2	1.24	Lausanne-Ouchy Railway.
Czecho-Slovakia	12 429	7 723	State Railways.

APPENDIX 3.

Reply of the Swiss Federal Railways to the detailed questionnaire relative to Question XV « Co-operation of the staff towards increased efficiency and its participation in the profits. »

FIRST PART.

FIRST SECTION.

QUESTIONS 1-4.

To stimulate the interest of the staff in the prosperity of the undertaking, bonuses (called « premiums ») are granted to the officials, clerks and workpeople who present utilisable proposals calculated to simplify, improve or render more economical the administration or the operation. These premiums are of three sorts, and may be cumulative :

a) Grant of honorable mention;

b) Payment of an amount in cash;

c) Allowance of extra leave, not exceeding 30 days.

From the 1st May 1927, the date of the entry into force of the regulations delivered in this general service communication (abbreviated to c. g. s.), till the end of August 1928, there have been presented to the Administration, in round numbers, 700 proposals, of which 253 have been definitely dealt with. In 84 cases, no premium has been granted. In 85 cases, honourable mention was accorded, and in the other 84 cases honourable mention has been accorded and money premiums paid ranging from 20 to 150 francs. The total amount of these 84 rewards in cash is in round figures 3 000 francs. None of the proposals put forward up to the present has been of a nature to secure a large direct profit for the Federal Railways, nor to give rise to appreciable innovations in the operating service.

In the terms of the general service order (c. g. s.) No. 8, *rewards* can be allotted, charged to a special fund called the « Guyer-Zeller fund », to all servants on the Federal Railways or their survivors :

a) for acts by which the said servants have distinguished themselves in the operation of the railway, in the supervision of the track, in the accomplishment of maintenance work on the railway or of constructional work carried out on the domain or outside the limits of the railway, but which bears a relation to its operation;

b) for acts accomplished with a view to averting or preventing accidents, provided they have been appropriate to the securing of that end;

c) for the discovery of attempts against the safety of the service or of the passengers, or against the property of the railway or its passengers, also for the detection of the authors of such attempts.

In 1927, for example, there were paid in virtue of these arrangements 86 rewards, representing a total of 1 620 francs.

Since 1923 we have been allotting to the personnel of the ticket printing service, excluding the office staff, in accordance with the regulations, premiums for work done over and above the normal work. The result has been very satisfactory. The servants, stimulated in their work, produce more, and manage

to earn by the end of the year premiums amounting to as much as 500 francs, which represents for the Administration an appreciable saving in staff and machinery.

QUESTION 5.

No. 1. Each time a train agent notifies a case of abuse of season tickets, for a limited number of trips, or general sea-season tickets, free travel passes or employees' tickets, he is awarded a premium of 5 fr. per ticket or pass.

In this connection, we would specially point out that with us, access to the platforms being free, the checking of tickets is exclusively effected by train agents, and is carried out in or — on the trains themselves.

No. 3. In some large goods stations, there are allotted, *as an experiment,* premiums to the chiefs of gangs and to the workmen for the handling of goods. This premium is calculated on the weight of goods handled above the weight fixed as the normal output (tonnage premium). The experiments made up to the present have been satisfactory. It has been calculated that this system permits of economies up to 70 centimes per ton above mentioned.

Except for the premiums mentioned in Nos. 1 and 3, and subject to what is going to be said with regard to train staffs (Nos. 8 and 9), no premiums for work or special bonuses are granted to employees in the categories enumerated under Nos. 1 to 7 of Question 5.

Nos. 8 and 9. The train staffs : head guards, guards, conductors and brakesmen) receive, in addition to their fixed wage, the extra allocations provided for in Regulation No. 22, i. e. :

Mileage awards (art. 2);

Extra for head guards service (art. 3);

Hourly award for unloading, loading and shunting services (art. 4);

Lodging allowance (art. 9);

Allowance for tickets withdrawn (art. 10);

Award for reserve service (art. 5);

Award for service on constructional trains (art. 6);

Award for exceptional employment in station service (art. 7);

Award for temporary train service in other depot stations (art. 8);

Allowance for meals obtained away from home, as per c. g .s. No. 72/1918, appended to Regulation No. 22.

The extra allowances for head guards consist, according to article 1 of regulation No. 22, of extra pay per day of service and a lodging allowance (when sleeping away from home).

These extra allowances have the character of items of wages.

QUESTION 6.

No. 1. Locomotive enginemen. — There are allotted to the chief drivers (principal drivers), in addition to their fixed regular pay, the awards provided for in art. 14 of Regulation No. 22 for each hour of absence from their home station and for each night passed away from home, with the extras arranged under (1) by c. g. s. No. 72/1918 attached to the said regulation.

The drivers and firemen receive, in virtue of this Regulation No. 22, the awards and extras below :

Mileage awards (art. 15);

Awards per hour of service and staying away from the regular station (art. 15);

Extras for certain trains and certain lines (art. 16);

Extra for sleeping away (art. 16);

Extra for temporary work at other depots (art. 16);

Allowance to drivers called on to deputise for the depot chief and to firemen acting temporarily as drivers (art. 16);

Further :

Special allowance of 1 centime per kilometre for drivers carrying out alone (with-

out assistants) the duties of electric locomotive drivers :

Allowances for meals taken away from home (c. g. s. No. 72/1918, attached to Regulation No. 22).

No. 2. Under certain conditions, premiums are granted to employees of the track supervision and maintenance service, of the station and train service, also the traction and workshop service, who discover damage or defects in rolling stock or permanent way. These premiums vary between 1 and 10 francs according to the importance of the defect discovered. They are laid down in Service Order No. 314 of the Directorate of the old IInd Division, of 25 January 1905, the application of which is extended, in practice, to the whole system.

No. 3. Nil.

No. 4. Train controllers are also entitled to the extra allowances provided for in art. 14 of Regulation No. 22 and in (1) of c. g. s. No. 72/1918 appended to this regulation.

The *steamboat staffs* also receive, in addition to their regular wage, special allowances provided for in arts. 21 to 28 of Regulation No. 22 and by c. g. s. No. 72/1918.

Question 7.

See what is said above with regard to Question 6, No. 2.

Question 8.

No. 1. In certain stations, the handling of goods is in part carried out by contractors, who are paid according to circumstances, by the hour or by the ton handled.

No. 2. In addition to the ordinary pay and premiums, bonuses and allowances mentioned in the foregoing replies, bonuses or special allowances can be granted in virtue of the following legal or regulation provisions :

a) Art. 49 of Federal Law on the Status of Officials : bonus of one month's wages to any official, clerk and workman attaining 25 and 40 years service;

b) Regulation No. 47 : allowance for night work;

c) Provisions No. 233 : allowance to permanent way and telegraph staff for unusual night work;

d) Provisions No. 234 : allowances for work in long tunnels;

e) Provisions No. 33 : reward for extra work;

f) Art. 10 of Regulation No. 25 : Extra wage payable to day workers employed temporarily on work of a particularly arduous nature (night fireman service; boiler inspection or cleaning service carried ou as an extra duty).

SECOND PART.

No. 1. The staff is not interested in the profits of the undertaking. It is not granted, from these profits, premiums or bonuses of any sort.

No. 2. The staff, whatever may be its rank, may subscribe for Federal Railway loans or acquire stock like any private person, but enjoys no privilege in this respect.

SECOND PART.

A. Collaboration of the staff in the Administration is allowed, in order to stimulate its interest in the good working of the enterprise. This is exercised in the following manner :

1. Although the law does not require this (see art. 6 (2), *a*, and art. 8 of the Federal Law concerning the organisation and administration of the Federal Railways), the Board of Administration counts amongst its numbers a representative of the staff;

2. This same law (art. 31), and art. 67 of the law on the status of the staff, provide for the institution of Staff committees, which have an exclusively con-

sultative character. In virtue of these legal arrangements, our Administration created, in 1926 and 1927, after a trial previously made, « staff committees », and also « workshop employees' committees », the organisation and privileges of which are set forth in Regulation No. 7 and in the General Service Order No. 204. These institutions contribute very happily to the increase of the interest of our servants in the undertaking.

B. The juridical situation of the staff with regard to the Administration, its duties and its rights, in particular wages, are regulated in the Federal law, already cited, on the status of the staff. This provides, in its art. 65, for the institution of a « Committee of Parity », an exclusively consultative body, of which the President and the half of the members and deputies are nominated by the Federal Council, the other members and deputies being designated by the staff, not only of the Federal Railways, but of all branches of the Federal Administration. The functions of the Committee of Parity are defined in Art. 66 of the said law, to which we beg to refer.

C. Since the month of May 1924 we have been publishing, in the three national languages, a « Bulletin des CFF » — « SBB-Nachrichtenblatt » — « Bollettino delle SFF » (*Bulletin of the Federal Railways*), a monthly organ which is distributed free to all the staff. Its purpose was defined in these terms in the first number :

« The *Bulletin* is, in the first place, intended to inform the whole of the staff of the Federal Railway Administration regarding the working of the most important undertaking in our country. It will supply to the managing organisations of the Administration the possibility of showing the staff the economic conditions under which the undertaking is obliged to work, of leading it to a better conviction of the utility of the methods by which the Administration seeks to attain its end, of strengthening in it the sentiment that thoughtful and persevering efforts are indispensable to the prosperity of the Federal Railways. But, and we insist on this point, the Bulletin must also be a constant source of professional instruction and improvement. Technical questions of every order will be treated exhaustively therein; regulations and instructions will be explained with care, innovations, explained in detail. Suggestions tending to simplify and to improve the service will always be welcome. »

The columns of the Bulletin are open to the staff, and payment is made for articles worthy of being published.

D. The interest of the staff is, again, indirectly stimulated by various *social provident institutions* of a very well developed kind, to which the Administration contributes financially in very large measure. The chief are the pension and assistance fund, the sickness insurance fund and the accident insurance.

E. Numerous institutions have as their object the *facilitation of the work* of certain categories of the staff. We cite, in particular : the canteens, where complete meals are served; bars for refreshments, food, milk and non-alcoholic drinks, kitchens where the workmen can warm up the food they bring with them to work; cooking apparatus which the Administration places, with the necessary service, at the disposal of the construction and permanent way maintenance staff for the preparation of their food; clothes drying arrangements; baths, showers and lavatories; reading rooms.

In the same order of ideas, we must also mention the distribution to certain categories of the staff of non-alcoholic drinks during the fine season, and hot drinks in the winter.

F. Finally, we have to cite the *insti-*

tutions of an economic nature, as follows, for the welfare of the staff :

1. *Service dwellings* are allotted, for a modest rent, to a large number of officials, clerks and workmen in the station service, the permanent way maintenance and supervision service, and in the hydro-electric plants.

2. The *Savings Bank* of the Federal Railways, (Instructions No. 24) and the *deposit accounts* (c. g. s. No. 48/1927) offer to the staff appreciable financial advantages.

The savings bank offers him a safe investment, on good terms, for his savings. The depositors can make regular lodgments therein, kept back from their monthly wage, and also voluntary deposits. They can effect withdrawals at any time. The financial advantage, for the depositors, consists of the fact that this bank allows an interest higher (by about 1/2 %) than the rate of the cantonal banks.

The deposit accounts offer to the staff the possibility of investing their savings, for three years firm, at a rate of interest still higher than that of the savings bank.

The development which these two institutions have assumed by this date authorises us to claim that the staff has recognised their advantages, and that they have attained their end, which is to stimulate the spirit of economy.

3. With regard to *housing,* the Administration assists the staff :

a) by granting, from its own capital, mortgage loans at low rates to co-operative building societies ;

b) by individual mortgage loans to railway servants, from the capital of the pension and assistance fund, for the purchase or building of houses, which must not, however, comprise more than three suites of rooms.

The article, « Institutions in favour of the staff of the Swiss Federal Railways », which will be found in No. 5 of the Bulletin of the CFF for May 1925, contains some detailed particulars of a part of the institutions of which we have just spoken.

THIRD PART.

In the course of the last seven years, we have succeeded, notwithstanding a very heavy increase of traffic, in reducing the number of our staff from 40 000 to 33 000 men, in round numbers. This alone is a testimony to the intelligent co-operation rendered by the staff to the Administration in its efforts to increase the output of work, and thus make operation more economical. It is true that the introduction of electric traction has contributed in a large measure to this reduction of staff. But in a general way, it must be said that all classes of employees are animated by good will in carrying out the rationalisation of the undertaking. It is incontestable that under the menace residing in automobile competition, the staff has still better appreciated the necessity of affording us their collaboration.

With regard to wages, we must say that the Swiss Federal Railways are of the number of railway undertakings which, in proportion to the cost of living, pay very high wages and salaries. It is very probably we who, of all the railway administrations on the European Continent, pay certain categories of staff the best. Of late years we have been inspired by the axiom: « We want a staff limited in number, but in return well paid ».

In our management report for the financial year 1927, we have expressed this thought in the following terms :

« The careful delimitation of the field of activity of the various services represents, in an economic organism as complex as that of a railway undertaking, an indispensable condition for the uniform

and fruitful collaboration of all the officials and workmen; it is also necessary for the simple and even working of the business. However, good regulations do not alone suffice. The success of any organisation depends, in the end, always on the quality of the staff. Now, the administration will only possess a capable body of officials if it can offer them favourable terms of engagement, pay and promotion. But to arrive at this in face of the competition we have to meet from other forms of transport, it is necessary for us to be able to employ only a small staff . In the administrative service, the number of employees required will be the smaller the more completely we succeed in avoiding duplication of work, in regulating the service in a simple manner, and in getting each official to bear his share of responsibility. By accentuating the responsibility of those who direct the services, whatever be the rank of these chiefs, we shall also develop in them the sentiment that all work must tend to the maximum output, which in these days is an absolute necessity. »

We take leave, for the rest, to refer to this Management Report for 1927.

Berne, 20 October 1928.

General Management of the
Federal Railways.

APPENDIX 4.

Abstract of made to the detailed questionnaire by the Czecho-Slovakian State Railways.

Essence of Question XV.

The result of any enterprise depends, above all, on three elements, viz :

a) on the manufacturer (the owner of the enterprise);

b) on the employees;

c) on the consumers (the public).

Ad. 1. The manufacturer is the creative force. He founds the enterprise, determines the locus, the extent and direction and all the details of the undertaking's activities; he provides the necessary capital; if occasion arises he gives up the enterprise.

Ad. 2. An element not less important is constitued by the work of the employees, the quantity and the quality of this work; in the preparation of estimates, the human factor certainly forms a variable element, representing sometimes the greater part of the cost, and elsewhere, if need be, only an insignificant percentage; but even in such cases the activity of the employees exerts a direct and indirect influence on the other elements.

Ad. 3. The consumer co-operates to a notable degree in the establishment of the selling prices, and has a great influence on the output of the enterprise, and consequently on the extent of its activities; as a consequence, apathy in public consumption, caused frequently by factors quite independent of the undertaking insufficiency of incomes, political conditions, etc.) may completely annul the profits of the enterprise; while on the other hand a good appreciation of the products may have as a consequence a larger output, higher prices and consequently a greater profit, in the acquisition of which the two first-named elements have had no credit. Of course, we must not lose sight of the fact that precisely one of the duties of the undertaker is to understand the consumer and to exert his influence on him in the interests of the undertaking.

According to the programme drawn up, it is in the first place the servants of the undertaking who are of interest to us. These latter must before all possess aptitude, and, secondly, good will to work to the best advantage. With regard to good will, we will speak of this anon; the question of the employee's aptitude is outside the scope of this question; we will suppose that it exists. In order that the employees may be capable of accomplishing their work, it is necessary to see to this both at the time of their admission and at the time of their initiation and subsequent instruction, and in addition at the time of the allocation of certain employees to certain tasks. Here there also comes into question the care with which the administration of the enterprise must proceed in seeking the most efficient method of working and in teaching it to the staff. (System of methods of working, study of economy of movement.)

The three elements which we have just enumerated have each their own interest for the enterprise.

For the owner, this is the largest possible profit, therefore the reduction of general charges and high selling prices; for the staff, stable employment and high remuneration for their work, and for the

consumer, low selling prices for a product of good quality (workmanship).

The interests of these three elements are obviously for the most part diametrically opposed to each other; and nevertheless it is necessary that not only the employees, but also the other factors, should show good will towards the enterprise, the good will of which we have spoken above, and without which the enterprise could not respond to the best advantage to the individual interest of this or that element. In order that all the elements may have this consciousness, and consequently this good will towards the enterprise, it is necessary that the interests of these three elements should not be opposed, but that they should be brought into agreement, and it is just one of the main tasks of the directing factor of the enterprise to do this; from this task in born the « public service ». From this point of view, organisation as a special branch of the service is a great aid to the undertaking.

The organisation of the enterprise has, in principle, two main tasks, viz. :

1. to establish a basis for the working in common of a greater number of units, a basis permitting and having as its object the avoidance of mutual hindrance in the work of different units, but on the contrary the making of these mutually complementary in an effective manner — in a word to permit the employees to work in a suitable, economical and satisfactory manner, and

2. to see that the employees in fact utilise these possibilities and work efficiently, in other words to see that the organisations *are constrained to work automatically*, efficiently, economically and well — that is, as demanded by the interests of the undertaking.

The organisation will also co-operate in many respects to regulate relations with the consumers (the public). As regards this question, we will revert to it later, if occasion arises.

What is of primary interest to us is the point (2) mentioned above. Here we are of opinion that the organisation must *bring into line the interests of the owner and the interests of his servants ;* it must above all see to the elimination, as far as possible, of causes of disagreement, and act so that the accomplishment of the duties of the employees shall be in direct correlation with the realisation of their personal interest. This interest may be negative or positive, i. e. the employee may work because it is in his interest to avoid penalties, or he may work to obtain some advantage, either moral or pecuniary. In the past, the negative interest was mainly counted on; if occasion arose, the positive moral interest; strictness displayed towards the employee, the menace of a penalty, perhaps even of dismissal, confidence in the conscience of the employee and the honorific certification of his work, were the ruling ideas in this direction. Pecuniary remunerations themselves were imprinted with the character of an honorific distinction. On the contrary, our material age, also the conditions around us constrain us to assume for the employee, in a large measure, his positive interest, i. e. material interest, and further, or more exactly as a consequence, to aim more energetically also at this direct correlation between the result of the work and the advantage obtained by the employee. This, therefore, is a very important task of organisation — to establish an *organising principle,* that is, the manner in which we bring into the enterprise the personal interest of the employee, in direct correlation with the effect of his work, or, in other terms, in which we interest the employee in the success of the enterprise. Further, the organising principle may also intervene in the regulation of the relations between the undertaking and the consumer (the public).

The methods by which different organising principles seek to attain the

object aimed at may be various, for example :

a) *discipline* (this alone is inadequate in the present times); piece work, rewards, honorary certificates, improved social position, high wages, etc., regular and independent in general or depending indirectly on the work done, methods which are of a primitive character and must not be introduced exclusively, but to which accessory recourse can be had;

b) *mechanical system*. In the progress of the work, the main role is played by machines; the machines accomplish the greater part of the work, set the pace for the work, and the human work done depends on the output of the machines;

c) *piece work system*, in which the employee obtains only the equivalent of the work effectively and well done, without having the guarantee of a minimum or firm remuneration;

d) *premium system*. The agent gets his pay, calculated for an average amount of work done, and further, he obtains for a surplus of output a premium directly proportional;

e) *system of participation in the total gross receipts*. The employee gets a fixed wage, and has, in addition, a fixed quota of all the gross receipts not acquired directly by him. This system is only suitable in exceptional cases;

f) *profit sharing system*. The employee, in addition to his pay stipulated elsewhere, participates in the profit to a predetermined extent. A difficulty arises with regard to the sharing of the profit, from the fact of a claim which is, moreover, just : the employees ask to be allowed to verify the amounts and the calculation of the profit, etc.; further, it is nearly impossible to obtain a direct relationship between the product of the work and the quota of profit;

g) *system of contract work*, in which the whole of the enterprise is split up into a predetermined number of lesser units, composed of several employees, whose task is identical and forms a distinct part of all the task of the enterprise. Each unit mentioned represents an independent contractor, and keeps its accounts in an autonomous manner. Its task must be limited and determined beforehand.

The activity of the undertaking must be fully covered by its distribution amongst the units mentioned; the units proceed reciprocally to the evaluation of their outputs, so that the units whose account is charged check automatically and in their own interest the units charging to their account. Each unit establishes its balance sheet independently, and fixes its net profit, which is shared by the members of the unit in question after various deductions. The contractor carries to the account of all the units the equivalent of his activity as regards the enterprise, in particular, thus, the interest on the capital involved, and participates to the extent of a fixed quota in the profits of the units.

This system implies the closed connection between the employee and the enterprise, for the employee participates both in the profits and (at least in a certain measure) in the losses of the enterprise, or of the unit, of which he forms a part, and his interest is that not only himself and his collaborators shall obtain the maximum production, but also that the general and other establishment charges shall be as low as possible; it is even also in his interest that the enterprise shall be occupied in a uniform, constant and satisfactory manner. The advantage presented by this system resides above all in the fact that it is not one-sided like the other systems, but takes into consideration not only what the employee has accomplished, but also if he has omitted to foresee anything or to prevent anything not merely as regards his own work but also that of his comrades. Thus there are set in opposition,

not the interests of the contractor and of the employee, but the interests of the different employees, solely regulated by the contractor, and, in sum, concordant with his interests, which renders it possible to obtain a rapid, effective, mutual, cheap (it may be said) automatic check on everything taking place in the undertaking.

From the interpretation of these fundamental systems and from their adaptation to concrete conditions there result still other systems, responding, however, to some of the principles mentioned above. The exclusive employment of a single system would not be practicable; on the contrary, we know that various establishments always apply in principle a single system as the main and controlling one, while the other systems complement the main system and support the main system in particular where the controlling system is inadequate. So far as concerns the railways specially, it is necessary to recognise that they form enterprises so vast and so heterogeneous, by the diversity of their various branches of service, that a single system would hardly suffice; for this reason it will be necessary to employ several systems, according to the exigencies of this or that class of work.

Measures contemplated for the future.

While fully recognising the advantages and importance of the contract system of working (see above under *ad. g*), we must admit that the complete application of this system necessitates a long evolution, and that consequently it is necessary to be satisfied temporarily with the application of other methods which are much more simple.

However, in principle, we are of opinion that it is precisely the railways, which cannot fully avail themselves of the advantages resulting from the free fixing of selling prices, or, as the case may be, from their position of monoply, and which are consequently the more dependent on the official rates and on the costs of production — it is precisely the railways, we repeat, which cannot neglect the establishment and putting into effect of a principle of organisation which is advantageous for their work.

It is in this sense that *we consider as the most advantageous the mechanical system, the piece-work system and the premium system, which systems should be supplemented as may be required by lump sum payments and bonuses.*

With regard to the premiums, we propose to introduce specially, or as the case may, be to improve the premium system, paying :

a) for savings in time realised by intensive output, i. e. for the increase of the quantity of work furnished, premiums for rapidity;

b) for the improvement of the quality of the work, premiums for quality;

c) for economies in material, plant, mechanical energy, etc., *premiums for material*;

d) for the economical circulation of vehicles and the rational utilisation of the floor area and capacity offered, premiums for utilisation of rolling stock.

Idea of modern capitalism, soi-disant the most rational.

The principles of modern capitalism :

« Short duration of work, high wages, intensive output of work » — must be judged from the angle of the output of the undertaking. For this reason, their application must be studied in a precise calculation, with the object of not loading the expenses of the undertaking with a disproportionate increase of the charges relating to labour, while of course taking into account any increase in output. These principles, therefore, can only be applied in so far as the increase

of expenses due to shorter working hours and higher pay may be at least compensated for by a higher efficiency and better output of work.

However, the practical application of these principles depends on the whole of the economic conditions.

As to our opinion on industrial affairs considered as a « public service », we may add the following :

We have already declared above that the prosperity of an enterprise depends not only on the undertaker and the employee, but also on the consumer. It is consequently advantageous for the enterprise if the contractor knows how to bring into accord the interests of the undertaking and the interests of the consumer, which is just what constitutes the essence of a public service. This fact will clear up the old disputes between capital and labour; these two factors must be, in reality, excluded from the distribution of the profits which returns to the consumers, i. e. to the public; they have only a right to a remuneration representing the equivalent of their merit in the prosperity of the undertaking.

We recognise this theory as just, for, even if the profit be absorbed by the cost of production, the output, and the prosperity of the undertaking are increased, the selling prices are lowered and the whole level of existence is improved. Of course, full success can only be expected from the general introduction of this principle.

In railway enterprises, this principle is theoretically applicable as in any other enterprise. In the State railway enterprises, the profits of which are paid wholly or partly into the coffers of the State, the « public service » is already realised in a certain measure, that is, indirectly, since the receipts of the State arising from the railway profits reduce the burden of taxation. Of course, the « Ford service » has, as its object, to advantage the consumers *directly,* and it would certainly be preferable for railway enterprises to devote a predetermined part — non-facultative — of the profit to the direct interest of the public — we mean to measures aiming at the improvement, acceleration, greater safety and more economical working of the railway service.

APPENDIX 5.

Abstract of made to the detailed questionnaire by the Bulgarian State Railways and Ports.

Reply to the 2nd Part (final).

The interest of the staff in the results of the enterprise has sensibly increased at the same time as the sense of the public interest has developed in the employees. Otherwise, thanks to certain bonuses, emulation to carry out work with more intelligence and initiative has been developed. Clerk, artisan and labourer continually take more account of the aims and intention of the undertaking. They become continually more capable of a better understanding of the efforts of the managing staff towards a rationalisation of the enterprise, according to scientific methods and taking into account local conditions and material possibilities, which fact contributes to the better development of the enterprise and the increase of its profits, also of the services rendered to private citizens and to the national economy.

Reply to the 3rd Part.

Experiments made, and experience acquired in practice, have shown that the more accentuated tendencies, particularly since the war, of modern capitalism towards rationalisation, i. e. towards the realisation of economic order, promise a favourable solution of the grave questions such as the crises and the social question which, during the second half of the XIXth and the beginning of the XXth century, have agitated the political and business worlds. If, at first, an anomaly appears in the laws of nature and above all in those of social and economic life, this anomaly tends usually to disappear as soon as the essence of such law is investigated.

Now, to-day it seems more and more clear that the tendency of modern capitalism is to abandon the accumulation to its exclusive advantage of large profits, and, under the influence of the new theories, to take into consideration, as the object of industrial enterprise, the public interest as well, and this tendency conduces to a more sincere co-operation between capital and labour.

From these two ideas, rationalisation and co-operation, there must result high wages for the staff, but very intensive work and short working days, which will have as an inevitable consequence a more devoted activity on the part of the staff, and simultaneously a reduction of cost prices.

The Management of the Bulgarian State Railways considers that the interests of capital, labour and the public are at bottom identical. The new conception of industrial enterprise in the sense of « public service » must above all find its application where the railways belong to the State and are, in a small country, the largest enterprise. Outside of their methodical development, of the great services which they will render to the nation, they will at the same time be able, in a small country, to serve as an example for the popularisation of these ideas in the world of business, and their progressive application.

[621. 132.8]

REPORT No. 5

(Germany)

ON THE QUESTION OF LOCOMOTIVES OF NEW TYPES; IN PARTICULAR TURBINE LOCOMOTIVES AND INTERNAL COMBUSTION MOTOR LOCOMOTIVES (SUBJECT V FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION) [1] [2],

By Professor NORDMANN,

Reichsbahnoberrat, Headquarters of the Deutsche Reichsbahn Gesellschaft (German State Railway Company).

Figs. 1 to 31, pp. 262 to 305.

INDEX OF CONTENTS.

(1) This question runs as follows: « Locomotives of new types; in particular, turbine locomotives and internal combustion motor locomotives. Construction, efficiency, use and repair ».

(2) Translated from the German.

I. — Introduction.

The reciprocating locomotive in use on the Deutsche Reichsbahn has, during the last few years, attained a high degree of thermal efficiency as a result of detail improvements, notably by increasing the superheat. These improvements have not received sufficient appreciation in comparison with other constructional details which are all the more welcome because they have been introduced without modification of arrangments proved in the course of working and maintenance. Concurrently with the development of locomotives of normal design, many large Railway systems have not neglected the production of locomotives designed to give improved thermal results.

Railway Administrations are much more willing to undertake the tests of such locomotives, when they possess a well organized test department, which is able to analyse in detail the economy and the working control of such engines and with the knowledge gained, to envisage the possibilities of the development, not only of the complete locomotive but of its component parts. The Deutsche Reichsbahn, among others, has not omitted to undertake the building and test on a large scale, of turbine, high pressure and Diesel locomotives. The design of these locomotives will be described in the following pages in the order of their construction.

II. — The turbine locomotive.

1. — General.

The turbine and the high pressure locomotives carry over from the locomotive of regular design, the utilization of *steam* as the working medium for the thermal processes.

One can deal with the heat gradient of the reciprocating locomotive, which in late years attained remarkable results owing to increase in the superheat, in two ways. Either one can utilize the *lower limit* of the heat and pressure gradient to the point *of condensation*, or in the other direction, one can extend the heat gradient upwards by increase of pressure extending into the region of so called high pressure or further still to pressures which are far above those used in the normal locomotive boiler. The former path leads towards the turbine locomotive, the latter towards the high pressure locomotive. Finally both objects could conceivably be reached by a combination consisting of a high pressure turbine condensing locomotive.

The turbine locomotive owes it origin to the fact that it is almost impossible to obtain a sufficient reduction of steam pressure in the *reciprocating* locomotive. In order to extend the steam diagram sufficiently, the size of the low pressure cylinder must be so enlarged that it can no longer be kept within the limits of the loading gauge, besides which such a large cylinder would call for heavy gear and would cause resistance at starting.

In contradistinction to the reciprocating locomotive, the turbine locomotive is remarkable because it permits of the expansion of the steam by easy stages to the condenser pressure, so that it operates in the region of *low pressures* with better thermo-dynamic results. In this direction, the good thermodynamic results of the reciprocating locomotive working in the region of the *higher pressures* have been taken advantage of by the Reichsbahn in a very interesting experiment in the course of which a turbine was installed behind an ordinary

reciprocating engine using the normal boiler pressure the turbine being so arranged as to drive some of the axles of the tender.

One must not expect such a great advance in efficiency from a condensing locomotive as compared with a simple locomotive using similar pressure and superheat, as has been possible in stationary engine practice. The turbine locomotive, because of the condensation of its steam and the resulting absence of its blast pipe, cannot obtain the high steam output from its boiler, unless a special auxiliary is provided, such as a fan to blow up the fire. No such auxiliary, with its consequent steam and coal consumption is necessary with the normal locomotive having exhaust to atmosphere.

Moreover the extraction of the heat from the condenser calls for arrangements to cool the circulating water, which in practice usually consists of one or more steam driven turbine fans. It is also impossible to raise such a high vacuum as is the case in fixed power stations, if as in the case of the Zoelly engine, the condenser is cooled by water (evaporative cooling) with only restricted water storage capacity, or as in the case of the Ljungström engine, the condenser is air cooled.

The first two large locomotives built for test purposes were, as is well known, the Swedish engine designed by Ljungström and the Swiss Zoelly design. Desiring to build a turbine express locomotive, the Fried. Krupp Company approached the Reichsbahn, with an offer to build such a locomotive on the Zoelly system of which they were the licensees. The Reichsbahn agreed to the building of the locomotive and gave the Zoelly system the preference over the Ljungström system which it had already investigated.

The Ljungström design in which the boiler carriage is pushed in front of the engine does not appeal to German ideas as being perfectly safe when rounding curves at high speeds.

The position of the condenser on the tender is necessary because in order to avoid the large flexible vacuum connections which are difficult to keep tight both turbine and condenser must be carried on the same vehicle. Further the various flexible leads for the various high pressure and superheated steam services for the driving tender, which are peculiar to the Ljungström locomotive, appeared liable to fracture by fatigue.

Another feature that weighed against the Ljungström design was that the costly gearing had, when reversing, to be unmeshed and reinmeshed and might well be damaged during the process.

Finally in consequence of air cooling the vacuum was to a much greater extent dependent on atmospheric conditions than would be the case with a water cooled (evaporative) condenser.

The choice of an express locomotive as the type to be used for experiment, was decided on after the possibilities of the development of the turbine locomotive had been already shown as a result of the trials of the first large locomotives, because an express engine implies a locomotive of large size, which would provide a more reliable object lesson in the matter of accurate consumption measurements as well as practical working statistics for coal consumption, than would be the case with a small engine.

Secondly there was the weighty argu-

ment that the express locomotive makes fewer stops in everyday working than either a passenger or goods engine. The turbine locomotive has, as the Reichsbahn experiments showed, a really good starting torque, but the increase of speed is not, as in the case of a reciprocating engine, accompanied by a steam consumption rising in proportion to the increase of speed, but by a consumption of steam at low speeds, based on the flow through the turbine nozzles. These unfavourable peculiarities do not show up so much in the case of an express engine which from the nature of its duties does not have to get up speed so frequently.

There is also the further fact that the auxiliaries of the turbine locomotive, such as those which maintain the vacuum in the condenser during the stoppages of the main turbine, must be kept at work so that the necessary vacuum shall be available for a resumption of travel under steam. This unfavourable influence from stops is not so prominent in the case of a locomotive working a service calling for very few stops.

The second turbine locomotive, that built by Maffei of Munich for the Reichsbahn, is not fitted with a Zoelly turbine, but is of the same general design with turbine condenser and cooling tender and is likewise an express locomotive. The turbine driven tender was built for the Reichsbahn by Henschel, of Kassel, attached to an existing reciprocating locomotive and has in its turn a Zoelly turbine. Here we are concerned with a passenger locomotive, but as a consequence of the large share of the power provided by the reciprocating engine, the raising of speed and the number of stops do not play the same role as in the case of a pure turbine locomotive.

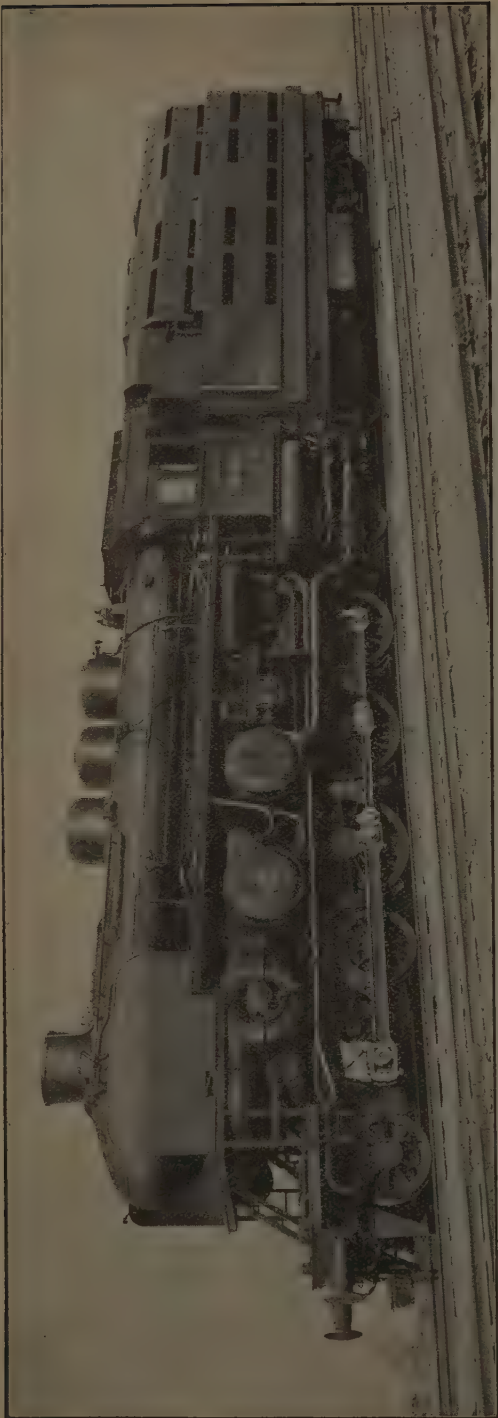


Fig. 1. — View of the Krupp turbine locomotive.

2. — The Krupp-Zoelly turbine locomotive.

The Krupp turbine locomotive (fig. 1) was designed with the object of effecting a saving of at least 12 % as compared with the P 10 (2-8-2. 3-cylinder locomotive). The 2-8-2. was at that time the latest design of the Reichsbahn for heavy passenger and express train service; it was reckoned as very efficient and its consumption was known as being satisfactory.

2 *a*. — Boiler of the turbine locomotive.

The boiler of the turbine locomotive (fig. 2) shows the normal locomotive boiler; it is fitted with the usual grate with a dumping section. The most important difference appears in the smoke box, especially because it has been necessary to fit a suction fan owing to the absence of the exhaust and blast pipe. The fan is fitted in the same way as that on the Swiss turbine locomotive and is housed in a parabolic extension of the smoke box door, the door hinges serving as hinges for the steam and exhaust leads of the fan turbine. A further difference lies in the provision of an *air preheater by combustion gases* in the smoke box and lastly in the small auxiliary chimney built in a housing with the main chimney and which by means of a small auxiliary blast pipe, permits of the fire being blown up without the necessity of putting the fan in operation.

The boiler barrel differs only slightly from the normal design owing to the provision of a small steam generator which is installed in the steam space in the shape of a second steam dome. This small generator serves to make up the loss of feed water due to leakage as well as for the provision of steam for train

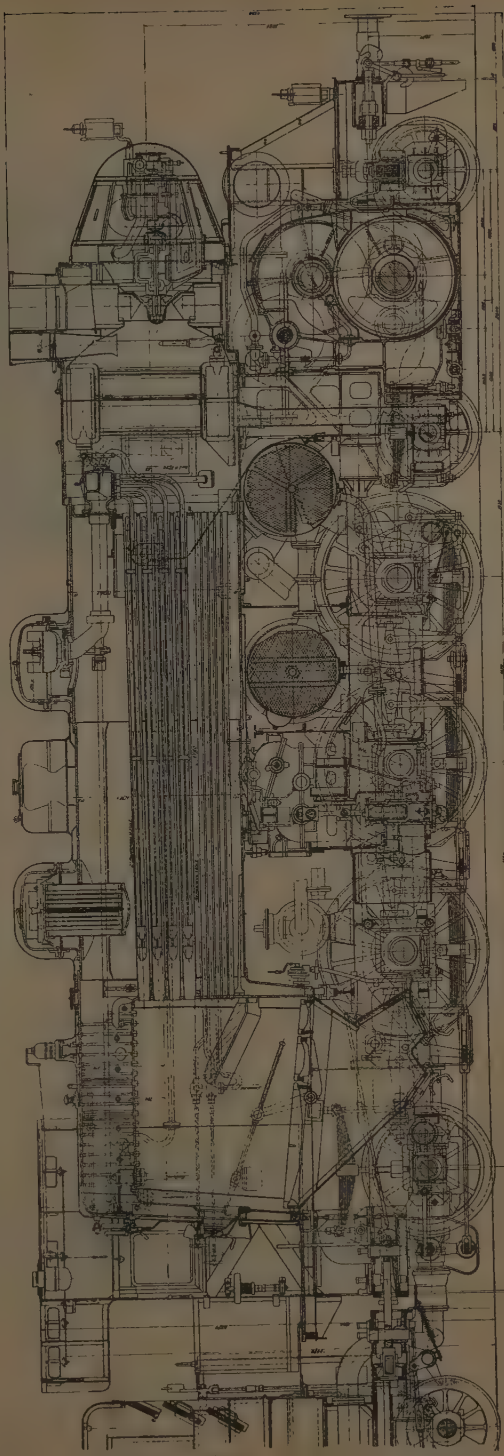


Fig. 2. — Longitudinal section of 4-6-2 turbine locomotive.

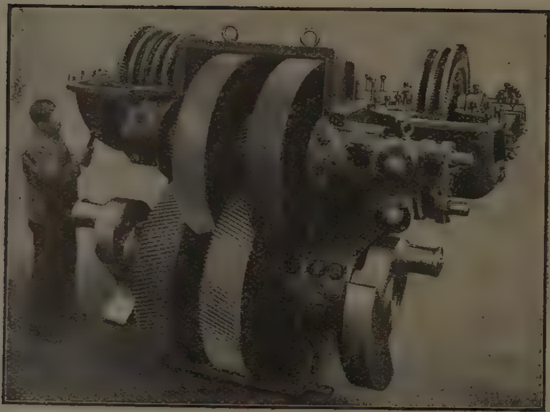


Fig. 3. — Driving gear of Krupp turbine locomotive.

heating. The superheated steam lost to atmosphere through leakage from the system must be replaced, not from the valuable pure water in the circulating system but from the raw water taken from the tender. The small generator is fed by a small automatic steam pump which continues to pump until the pressure in it stands at 4.5 atmospheres (64 lb. per sq. inch.), the pump then stops and only restarts when the pressure falls. The steam from this auxiliary generator can be passed through the steam heating system or it can be turned into the condenser from which on being condensed it returns to the boiler to make up loss.

This *pure water circuit* is undoubtedly an important advantage of the condensing turbine locomotive. It ensures the freedom of the heating surfaces from scale, and permits elimination of the usual washing out, which need only be carried out when stopped for some time, so that the resulting breaks in service and wages costs are saved. A further welcome result will be met with in the course of discussion of the trials.

The superheater of the usual pattern also supplies the auxiliaries with superheated steam.

2 *b*. — Driving gear, main turbine and condenser.

The turbine locomotive has the usual Reichsbahn bar frames, which are carried at the front end on a four wheeled bogie and are supported at the trailing end behind the three coupled axles by an Adams radial axle (fig. 2). On account of the high revolution speed of the turbine the diameter of the wheels is kept proportionally low, being 1.65 m. (5 ft. 5 inch.). The main turbine, a double turbine of which the forward turbine is for obvious reasons most highly developed, lies with its gearing and lay shaft almost over the center of the bogie and drives the coupled wheels by means of connecting rods (fig. 3).

The exhaust steam from the turbine passes to two transversely placed surface condensers which lie in front of the first and second coupled axles between the bottom of the boiler barrel and the top of the frames. The output of the forwards turbine is controlled by the opening or closing of large or small nozzles which were originally calibrated to pass 4 000 and 8 000 kg. (8 820 and 17 640 lb.) of steam per hour respectively but were subsequently altered to pass 3 000 and 6 000 kgr. (6 615 and 13 230 lb.) after it had been shown in the first trials that a total delivery from the boiler of 12 000 kgr. (26 460 lb.) per hour for both nozzles was too large for the heating surface. The reversing turbine has only one nozzle. The nozzle stop valve was at first worked from the footplate by means of a servo-motor but this arrangement was changed subsequently and a thrust-free hand gear substituted. The turbine can be worked under full nozzle pressure with three different deliveries representing 3 000, 6 000 and 9 000 kgr. per hour (6 615, 13 230 and 19 840 lb. per hour) for the two nozzles together; other deliveries are obtained by throttling by the regulator. The forward and reversing turbines work in separate casings. The toothed wheel gearing has diagonal teeth and are made from special Krupp hard steel. Lubrication for the turbine bearings, gear shafts as well as the teeth of gears is supplied by a *gear oil pump*, which il placed on the left side of the machine and is driven directly from the first gear shaft. The friction heated oil is passed through an oil cooler, which is supplied with cooling water from the water circulating pump. The front condenser is connected with the turbines by a bracket through which part of the steam from the working turbine passes to the condenser while part passes to the condenser by way of the idling turbine. At a later date the forward turbine was entirely cut off from the reversing turbine during *forward running* (see 2*e*). The steam which has not been condensed in the forward condenser passes on through the connecting tubes with the air to the second condenser. On account of the greater cooling output of the forward condenser the circulating water passes through it first and thus presents the coldest surfaces to the incoming steam. Easy access is obtained to the condenser tube blocks by the removal of the end covers, and the tubes which are easily changed are made tight in the plates by ferrules.

The condenser is made in two parts for constructional reasons.

2 *c.* — Auxiliary machinery.

The necessary pumps are assembled in one *pump group* which lies immediately behind the second coupled axle. A *steam turbine* drives through triple gearing, *the circulating pump for the cooling water*, the *boiler feed pump* and the *air brake compressor*. The feed pump is of the differential piston type, the circulating pump is centrifugal.

The water delivered by it does not only supply the cold water circulating system but also supplies a *jet air pump*, the pressure water for which in order to be as effective as possible is taken directly off the pressure main and after passing through the air separator of the condenser flows back in to the circulating pump suction. The jet air pump also removes the air from the condensers. The whole of the bearings of this

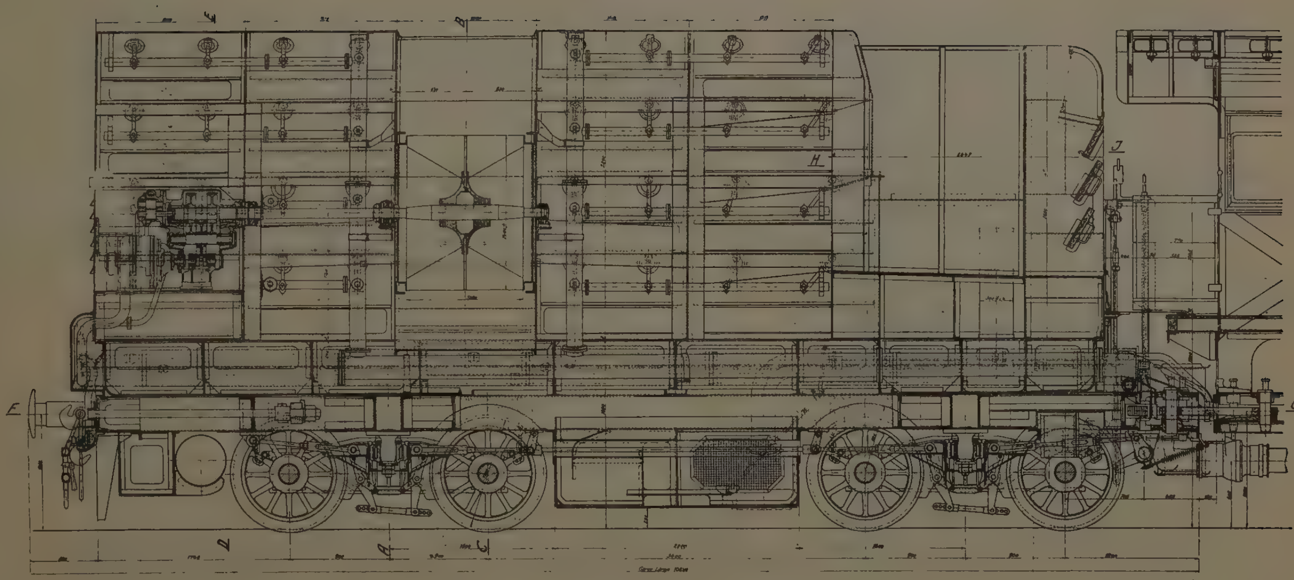


Fig. 4. — Longitudinal section of cooling tender.

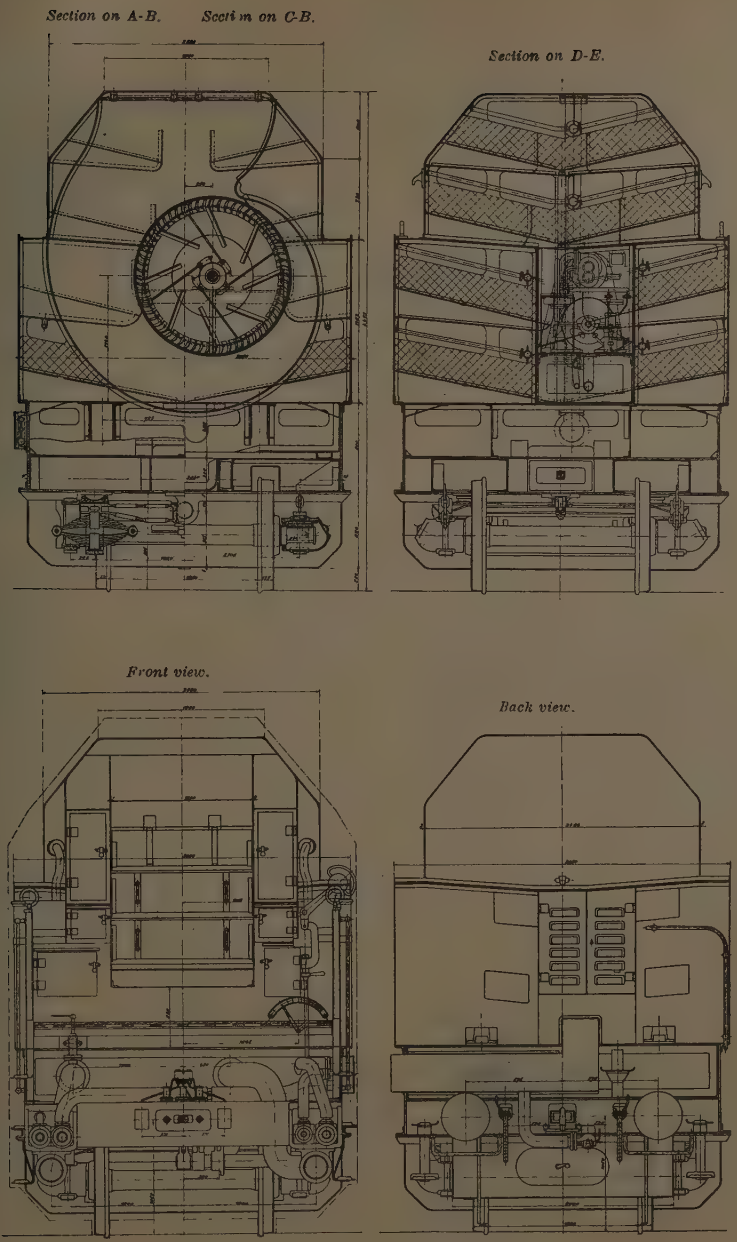


Fig. 5. — Cross sections of cooling tender.

machine assembly are lubricated by a common oil pump. The exhaust from the driving turbine is passed to the condenser.

2 *d*. — The cooling tender.

The cooling tender is a somewhat longer tender carried on four axles in two bogies of normal design (figs. 4 and 5). The lower part consists of the true water storage tank, but does not provide for the boiler feed in the usual sense; the feed water is contained in the pure water closed circuit and is in continuous circulation. It deals merely with the circulating water for the condensers which is returned to the tender for cooling. Only the small quantity of water, which is during cold weather used to supply superheated steam to heat the train or is used in small quantities to make up leakage loss, is taken for steam raising purposes. There is nevertheless quite an appreciable consumption of water because the condenser is of the film type and cools by means of water evaporation. In order that this film shall work satisfactorily, a sufficiently large wetted surface must be presented to the incoming hot cooling water, and the circulation of air over the cooling surfaces must be thoroughly carried on by means of a powerful fan. The circulating water is drawn by the pump previously described, through connecting pipes between the engine and tender which are provided with flexible joints and stuffing boxes to deal with the longitudinal movement and after being again heated in the condenser is returned to the tender through similar leads. The water after rising in the large vertical pipes is led to the various filming or spraying chambers on the tender and enters the horizontal distributing pipes, which are clearly shown in the elevation (fig. 4). These chambers are so arranged that the sloping screens which require carefull attention in order to prevent blocking by dust and cinders are easily accessible and lie on large numbers of so called Raschig rings (small plain cylinders of sheet aluminium which provide a large surface area with comparatively small resistance to flow. Aeration is supplied by a large fan placed between the cooling chambers, which takes its power from a steam turbine installed at the rear of the tender and is driven through the medium of double gearing. The fan draws air through the cooling chambers, which are connected with the outer air by a large number of slits cut in the side walls of the tender. These slits are provided with small guide vanes which are so arranged with reference to the forward motion of the engine, that they impede the entrance of dust and other matter into the cooling chambers. The fan drives the vapour laden air out through the top of the tender, without, as is shown by the trials, any tendency in winter, for the divided moisture to deposit ice on the roofs of the coaches directly in rear of the tender. The coal space on the tender which is well shown in the elevation, is built up to a considerable height but takes up so much space in the longitudinal direction that the usual sloping floor (to carry the coal forward) was in this instance inadmissable.

The heat exchange chart of the turbine locomotive is given in figure 6. The leading dimensions of the engine and tender are as follows :

Gauge	1 435 mm.	(4 ft. 8 1/2 in.)
Permissible maximum speed	100 km. per hour	(62 miles)
Revolutions of turbine at maximum speed	8 000 per minute.	
Reduction from turbine shaft to lay shaft	24.3 to 1.	
Crank circle diameter	630 mm.	(24 3/4 inches)
Driving wheel diameter	1 650 —	(5 ft. 5 in.)
Bogie wheel diameter	1 000 —	(3 ft. 3 3/8 in.)
Trailing truck wheel diameter	1 250 —	(4 ft. 1 3/16 in.)
Boiler pressure	15 atm.	(213.3 lb.)
Grate area	3.1 m²	(33.4 sq. feet)
Heating surface of fire box	12.5 —	(134.5 sq. ft.)
— — — heater and superheater	142.5 —	(1 534 sq. ft.)
— — — total exposed to fire	155.0 —	(1 668 sq. ft.)
— — — superheater	66.0 —	(710 sq. ft.)
— — — exhaust steam heater	8.5 —	(91.5 sq. ft.)
— — — air preheater	32.0 —	(344.5 sq. ft.)
Cooling surface in condenser, brass tubes 15/17 (5/8-11/16 inches).	220.0 m²	(2 368 sq. ft.)
Water content of boiler with 150 mm. (6 inches) over crown of fire box	7.0 m³	(247 cubic ft.)
Steam content	2.4 —	(84.7 cubic ft.)
Steaming area (exposed surface of water)	9.5 m²	(102 sq. ft.)
Boiler :		
Length between tube plates	5 000 mm.	(16 ft. 5 in.)
Diameter	1 600 —	(5 ft. 3 in.)
30 smoke tubes, diameter	125/133 mm.	(4 29/32 - 5 1/4 in.)
128 tubes, diameter	45/50 —	(1 3/4-1 31/32 in.)
Superheater, 30 elements	30/38 —	(1 3/16-1 1/2 in.)
Light weight of engine	104.2 t.	(102.5 Engl. tons)
Running weight of engine	113.7 t.	(111.9 Engl. tons)
Wheel base of engine	9 900 mm.	(28 ft. 5 3/4 in.)
Length over buffers	12 700 —	(41 ft. 9 in.)
Length of engine and tender over buffers	23 446 —	(76 ft. 11 in.)
Wheel base of engine and tender	18 440 —	(60 ft. 6 in.)
Tender :		
Wheel diameter	1 000 —	(3 ft. 3 3/8 in.)
Wheel base	7 000 —	(22 ft. 11 5/8 in.)
Water capacity	19.5 m³	(4 300 British gallons)
Coal capacity	6.5 t.	(6.4 Engl. tons)
Light weight	40.0 t.	(39.4 Engl. tons)
Running weight	66.0 t.	(65 Engl. tons)

2 *e*. — Trials.

The Krupp turbine locomotive was subjected to a very large number of test trips. The first, made in 1926 brought out the fact that there was no difference in coal and steam consumption between it and a good reciprocating engine. The Krupp firm thereupon subjected the complete turbine which had been made

by Escher-Wyss of Zurich to most careful stand tests and discovered that the reversing turbine needed a very high ventilating power, reaching several hundreds of H. P. and in addition to this, the vacuum in which the reversing turbine ran, left much to be desired. The remedy chosen was to cut off the

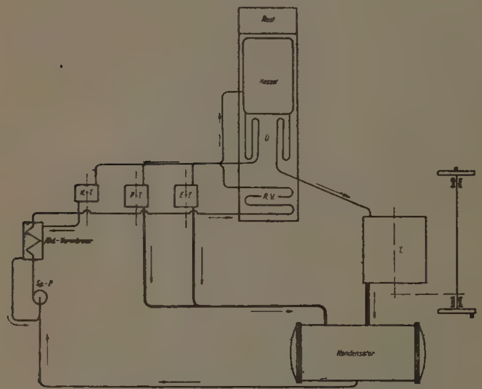


Fig. 6. — Diagram of 15-at. (213 lb. per sq. inch) turbine locomotive (Krupp, 1926).

Explanation: Ü = Superheater. — T = Main turbine. — FT = Blower turbine. — PT = Pump turbine (feed-circulation and air pumps). — Sp-P = Feed pump. — KT = Cooling turbine (tender). — RV = Exhaust gas preheater. — Rost = Grate. — Kessel = Boiler. — Abd.-Vorwärmer = Exhaust steam preheater. — Kondensator = Condenser.

reversing turbine, while the engine was going forwards by means of special automatic valves (Krupp's Patent) these valves being operated by a servo-motor. When running backwards these flap valves were set parallel to the guide vanes.

The fall in the vacuum after protracted warming up of the turbine casing was caused by a crack in one of the casing joints and this was corrected with a stud to stop the passage of the steam.

Only such tests will be described as were carried out in 1928 by the turbine locomotive after completion of all alterations.

The runs were made over the line between Potsdam and Burg on the Berlin-Magdeburg line which is almost level and free from curves. As a rule the load behind the dynamometer car was provided by an express locomotive fitted with the counter pressure brake and only for specially heavy loads were express corridor coaches attached to the test train. These well known test methods of the Reichsbahn provided extremely accurate tests, because with the assistance of the engine used as load, which does not during this period use its brake, acceleration is very rapid and the even running speed is very quickly reached. The tests were made at speeds of 60, 80 and 100 km. (37.3, 50 and 62 miles) per hour. The comprehensive temperature measuring installation of the German locomotive dynamometer car proved very advantageous in handling the large number of temperature readings which play such a large role in the analysis of locomotive working. Only a small selection from among the large number of curve charts are given with this paper and such as are given were taken at 80 km. (49.7 miles) per hour.

The *steam consumption per effective H. P.-hour* at the draw bar hook is shown in figure 7. The steam consumption does not in view of the use of two nozzles show a regular curve as is the case with the reciprocating locomotive.

The *steam pressure at the main turbine and the pressure in the condenser* are shown in figure 8. At small and medium powers with the small and large nozzles the full boiler pressure is attained at the maximum output appertaining to each nozzle. On the trips with both nozzles there was a drop of 5 at-

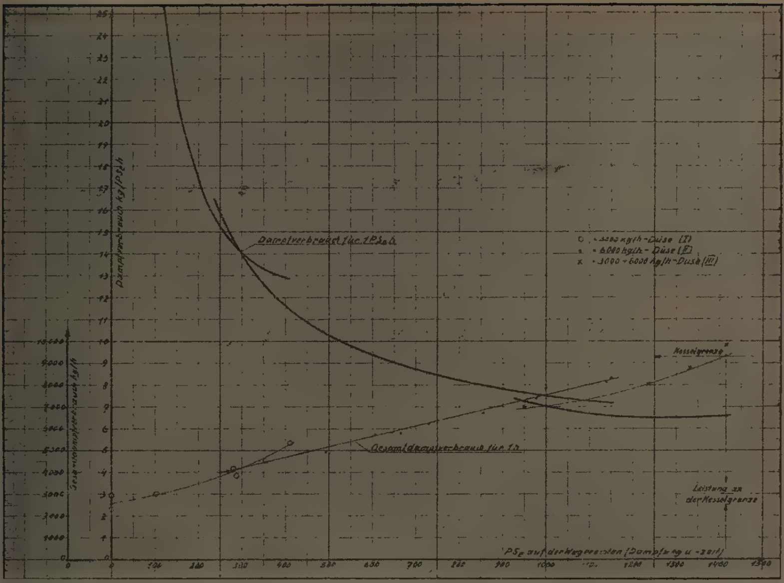


Fig. 7. — Total steam consumption per hour and per effective horse power-hour at the same mean speed (V = ∽ 80 km. = about 50 miles per hour).

Explanation of German terms : Dampfverbrauch *kg/PSeh* = Steam consumption in kgr. per effective horse power per hour. — Düse = Nozzle. — Gesamtdampfverbrauch = Total steam consumption. — Leistung an der Kesselgrenze = Power developed at limit of boiler capacity, — *PSe* auf der Wagerechten (Dampfweg u. -Zeit) = Effective horse power on the level (distance run and time under pressure).

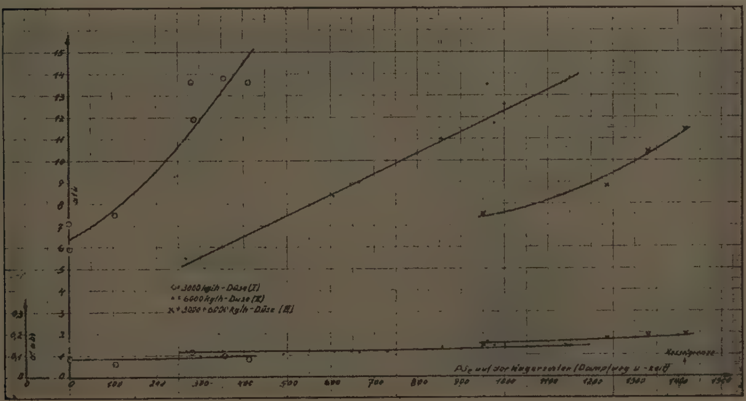


Fig. 8. — Pressure at main turbine and pressure at condenser for speed of about 80 km. (50 miles) per hour approx.

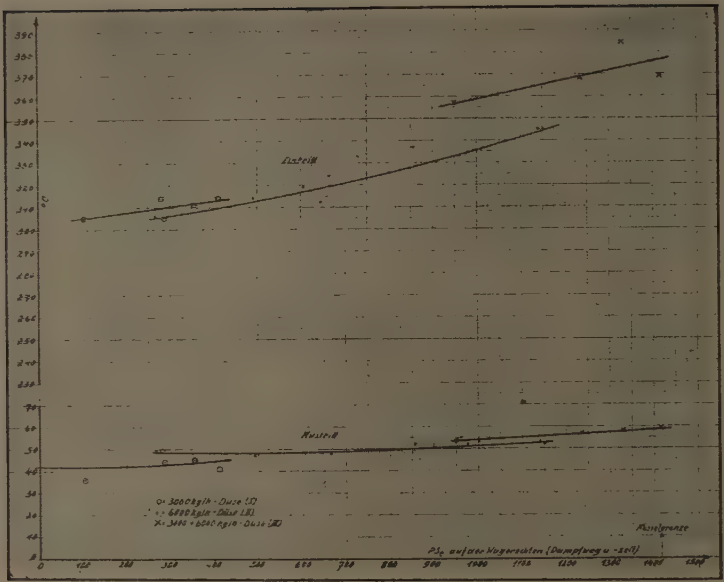


Fig. 9. — Temperature of steam at main turbine for about 80 km. (50 miles) per hour.

Explanation of German terms : Eintritt = Entrance. — Austritt = Exit.

mospheres or more. This behaviour of the pressure is entirely different from what happens with the valve chest pressure in a reciprocating locomotive, which at full loads shows the full boiler pressure less the loss due to pipe friction. The vacuum is throughout below 0.2 at. (2.84 lb. per sq. inch.) absolute and falls with the smaller outputs to 0.1 at. (1.42 lb. per sq. inch.). When it is remembered that it is a question of the capacity of a very restricted circulation of water to carry off the condenser heat, an average vacuum of about 0.13 at. (1.84 lb. per sq. inch.) may be considered as a good result from a cooling tender.

Figure 9 shows the steam temperatures at the turbine, which are again represented by three different curves, contrarily to the regular curve taken from a reciprocating engine. The temperatures reached at the higher outputs may be described as good. They follow the general rule for superheated steam temperatures in locomotive boilers, in that they increase with increasing load. The exhaust temperature i. e. the temperature in the condenser does not vary so greatly with the output. It rises also irregularly from about 42° C. (107.6° F.) when the engine is running light to about 59° C. (138.2° F.) with full load.

Figure 10 gives the steam pressure at the blower turbine as well as that of the waste gas fan turbine, and shows the expected result, that the pressure rises

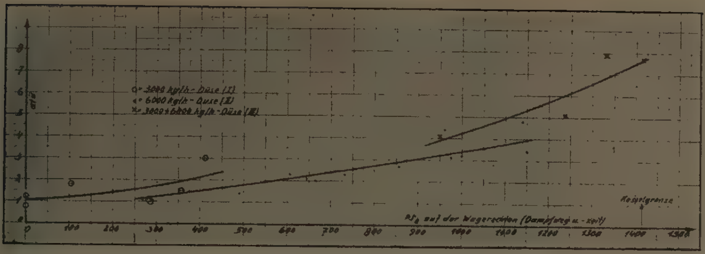


Fig. 10. — Steam pressure at blower turbine for about 80 km. (50 miles) per hour.

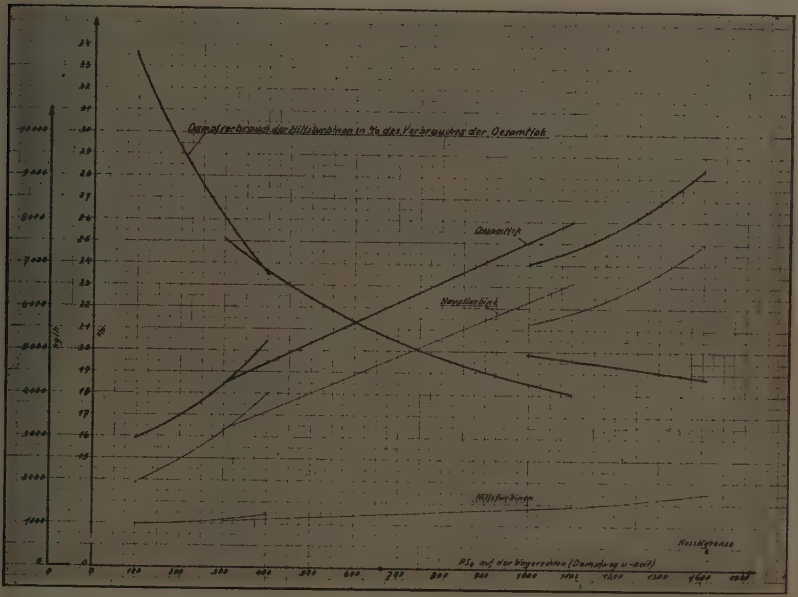


Fig. 11. — Proportion of steam used by auxiliary turbines of the total steam consumption for a speed of 80 km. (50 miles) per hour (approx.).

Explanation of German terms : Dampfverbrauch, etc... = Steam consumed by the auxiliary turbines as % of the total steam consumption of the locomotive. — Gesamtlok. — Whole of the locomotive. — Hauptturbine = Main turbine. — Hilfsturbinen = Auxiliary turbines.

quickly with the increased loading of the engine, or from 1 at. up to about 8 at. (14.2 to 113.8 lb. per sq. inch). This irregularity which is caused, but to a greater extent than in the case of other curves, by the methods of the fireman,

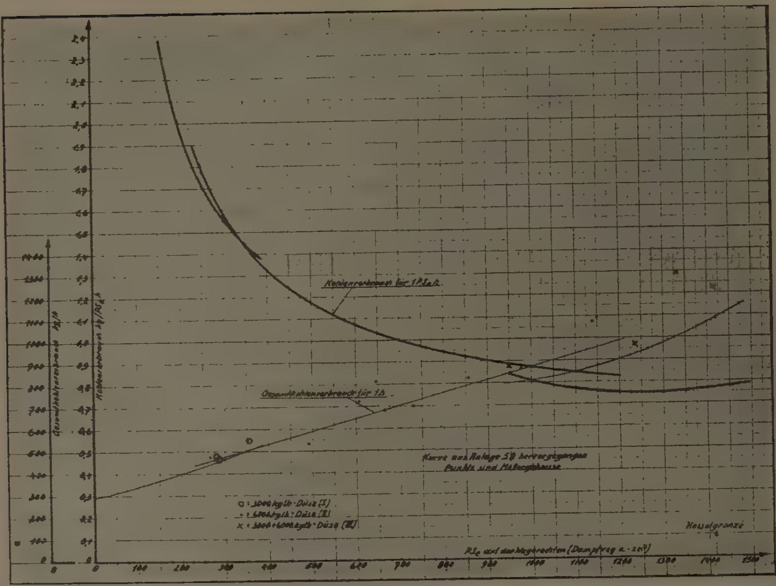


Fig. 12 — Total coal consumption per hour and consumption per effective horse power-hour for a speed of about 80 km. (50 miles) per hour (calorific power = 7 000 cal./kgr. = 12 600 B. T. U. per lb.).

Explanation of German terms : Gesamtkohlenverbrauch = Total coal consumption.
Punkte sind Messergebnisse = Location of dots obtained by measurements.

excites the desire to make the regulation of the auxiliaries automatically dependent on the main turbine.

A very important fact is confirmed by figure 11 which shows the proportion which the consumption of the auxiliaries bears to the total consumption of the locomotive. The consumption of the auxiliaries constitutes a very considerable percentage. It is shown in the above chart to be as high as 33 % at light loads and falls to 18 % of the total consumption in kgr.

The total heat consumption for the horse power hour reaches its lowest limit at a speed of 80 km. per hour (50 miles) and 1 250 H.P. with only 4 300 kgr.-cal. (17 060 B. T. U.) therefore much below that of the best reciprocating engine.

The temperature of the feed water (condensate) entering the feed water heater, which is heated by the exhaust from the cooling fan turbine, naturally varies considerably, at light loads it is about 40° C. (104° F.) and at maximum boiler output reaches 55° C. (131° F.). The temperature, after passing through the heater remains almost unchanged at all loads at about 95° C. (203° F.), the same is the case with the exit temperature from the waste gas heater which is about 124° C. (255.2° F.) so that 30° C. (54° F.) of heat is added by the waste

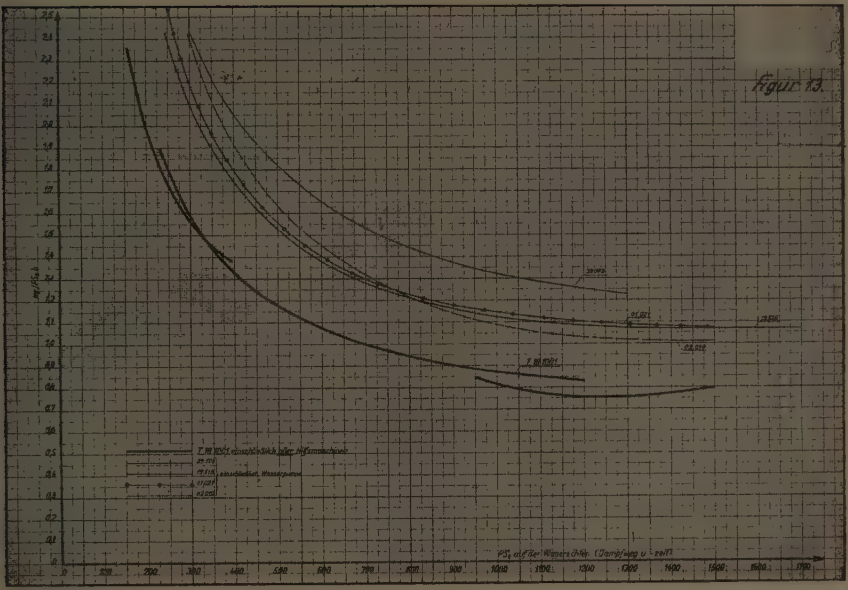


Fig. 13. — Comparison of turbine locomotive with other types : coal consumption per effective horse power-hour for speed of about 80 km. (50 miles) per hour. (Calorific value 12 600 B. T. U. per lb.)

Explanation of German terms: Einschliesslich *aller* Hilfsmaschinen = All auxiliary machines *included*. Einschliesslich Wasserpumpe = Water pump included.

gas heater. As a result of the waste gas heating the boiler efficiency is uncommonly good; it starts at 81.5 % with a heating surface output of 20 kgr/m²h. (4.1 lb. per sq. foot per hour) and falls so extraordinarily little, that at full boiler capacity it is as much as 79 %.

The coal consumption is therefore really low. The actual consumption according to figure 12 runs proportionally evenly and is at 1 250 H.Pe. which is about half the capacity of the boiler, a minimum of 0.75 kgr. (1.68 lb.) per effective horse power hour, the lowest coal consumption which has as yet been achieved by any steam locomotive.

Figure 13 shows the coal consumption of the turbine locomotive at 80 km. (50 miles) per hour in comparison with that of an engine of normal design, particularly in comparison with 2-8-2 local train engine, with which it was stipulated that the turbine locomotive should be compared. The chart shows that this locomotive has in the meantime been surpassed in the matter of coal consumption by the newer simple locomotive with increased superheat. The minimum coal consumption of the turbine locomotive shows an improvement as compared with the new simple engine of 40 % and an average of 25 %. At a speed of 60 km.

(37.3 miles per hour the turbine locomotive gives a 35 % better result than the 2-8-2 engine while at 100 km. (62 miles) per hour the result is about 33 % better.

The trips at steady speed were made as trips in front of express trains of different weights (from 400—600 tons) on the Berlin-Hannover-Bremen line 378 km. (235 miles) in length. This line is a flat country line with short grades of 1 : 200. The observed savings varied but little round 17 %, the influence of the stops during which the auxiliaries had

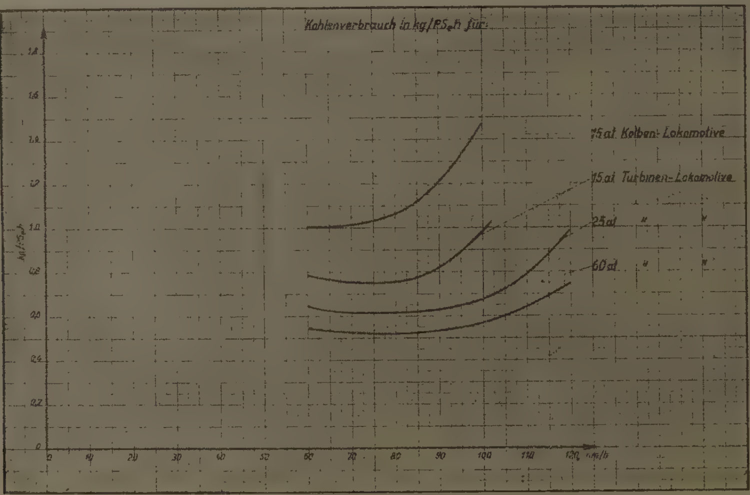


Fig. 14. — Probable coal consumption of turbine locomotive with higher boiler pressure.

Explanation of German terms: Kohlenverbrauch in *kg/PSeh* für : = Coal consumption in kgr. per effective horse power-hour for : . — 15 *at* Kolben-Lokomotive = 213 lb. per sq. inch piston locomotive. — 15 *at*/25 *at*/60 *at* Turbinen-Lokomotive = 213 lb./355 lb./853 lb. per sq. inch turbine locomotive.

to be kept in operation, was quite sufficient to reduce the saving as compared with the ideal for continuous steady running, by half, although the stops were not of excessive duration.

This result will be clearly understood after a glance at figure 11 because the consumption for the auxiliaries represents between 18 and 30 % of the total steam used for the locomotive as a whole at the output in question. Improvement in heat economy in the turbine locomotive in this particular service, where such stops must always be reckoned with, must now be sought in the direction of a reduction of the consumption of the auxiliaries by careful control. Krupp already have experiments under way. The intention is that the blower turbine shall be made automatically dependent on the steam consumption of the main turbine. The builders in cooperation with Escher-Wyss (Dr. Zoelly) hope in this way to still further increase the present excellent

economy now realised in continuous running, in the matter of coal consumption; increase of the boiler pressure will also serve to attain this object; the consumption figures which it is hoped to obtain are to be seen in figure 14.

On all the trial trips, those taking part were impressed with the splendidly quiet running of the turbine locomotive, as being equal to that of a vehicle with long wheel base; in a general way the running feels at least as quiet as that of a good express train coach, in that the masses of the turbine and gears rotating at high speed exercise a stabilising effect. The turbine locomotive is also the one locomotive which in the course of tests at the locomotive testing department at Grunewald, has not suffered from tube leakage after periods of lengthy heavy working. This is evidently to be traced to the practical freedom of the boiler from scale. With regard to the absence of scale, a maximum continuous loading of the boiler at 60 kgr./m² (12.3 lb. per sq. foot) was provided for as against 57 (11.7 lb. per sq. foot) for the normal locomotive.

The tractive power of the turbine locomotive is in addition very good; this was established in a separate test which was carried out in the following manner: the turbine locomotive was coupled with the dynamometer car between them, to another engine which was held by the application of its air brake, and the turbine engine was made to tow it, the regulator of the turbine engine being opened only very slowly. With full boiler pressure the pull was as follows with nozzle 1, 5 200 kgr. (11 464 lb.); with nozzle 2, 9 300 kgr. (20 503 lb.); with both nozzles 12 450 kgr. (27 447 lb.), this last representing an effective adhesive ratio at the draw hook of slightly over 0.2.

A trip was made tender first on which

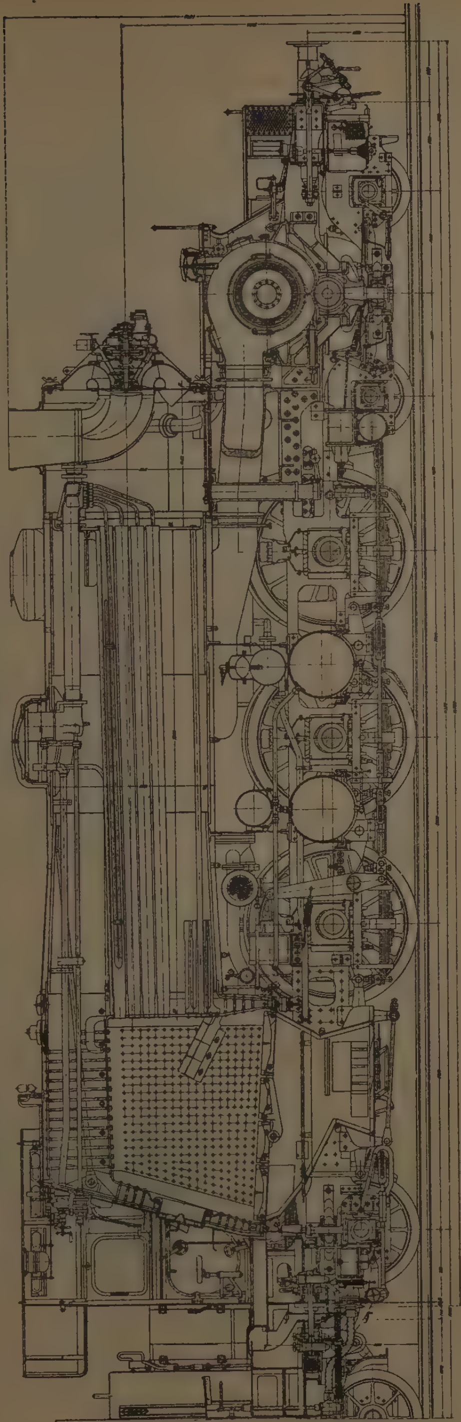


Fig. 15. — 4-6-2 Maffei turbine locomotive (J. A. Maffei, Munich).

the steam consumption of about 23 kgr. (51 lb. per H. P.-hour) was extraordinarily high although a speed of 54 km. (33.6 miles) per hour with a H. P. of 416 was maintained. This very large steam consumption is not surprising when the great fan effect of the multistage turbine is taken into consideration. The vacuum was at 75—80 % quite good, and the whole result for tender first running which will only occasionally have to be done, was without doubt satisfactory.

To sum up, the trials of the turbine locomotive were very instructive on account of the exhaustive mechanical and thermic analysis carried out and they will result in defects revealed in this first locomotive being avoided in future designs. The locomotive is now being overhauled and will soon be used to haul fast trains on the Essen Division of the Reichsbahn.

3. — The Maffei turbine locomotive.

The Maffei turbine locomotive which was built somewhat later than the Krupp engine can be more shortly described in respect of its general arrangement (fig. 15).

3*a*. — Description of the design.

The boiler of the Maffei locomotive is again a normal boiler in which the blast pipe is replaced by a suction fan. The waste gas feed heater and also the auxiliary generator for train heating are absent in the original design. On the other hand, the boiler is remarkable in that an attempt is made to raise the upper pressure limit to a height only possible in a locomotive boiler of normal design, by the use of exceptionally closely spaced staybolts, the pressure being 22 at. (313 lb. per sq. inch).

The turbine is as in the case of the Krupp engine placed over the bogie and drives the lay shaft, which is connected to the wheels by means of coupling rods, through double gear. The bar frames and the rear trailing axle are similar to the Krupp engine. The turbine itself is, in contradistinction to the Zoelly, not a pure pressure machine; a two-stage Curtis wheel is inserted in front of the six-stage equal pressure turbine. The reversing turbine, which delivers its exhaust into a chamber connected to the condenser is as the Krupp turbine, two-stage. Whereas in the Krupp machine the forward and reversing turbines were separated by the double gear which lay between them, the whole turbine assembly is here kept together about the center line of the locomotive. The gears are carried on either side of the turbine so that the crank discs of the lay shaft are utilized for the large gears, into which the two pinions engage. The larger gear wheels on the intermediate shaft are arranged in the same way as the power transmission wheels of electric locomotives. The admission of steam to the turbine is rather more finely regulated than on the Krupp engine. Both forward and reversing turbines have each four nozzle groups, which can be operated successively from the footplate by turning a shaft which opens the valves on the nozzles of the turbine required while closing the nozzles for the turbine, either forward or backward which is not required. The operating wheel is fitted with an indicator which shows the position in regard to the nozzles to the man on the foot plate.

The turbine exhaust goes into two water cooled surface condensers, which are carried longitudinally and not transversely (as on the Krupp engine), projecting above the platform. The Y shaped

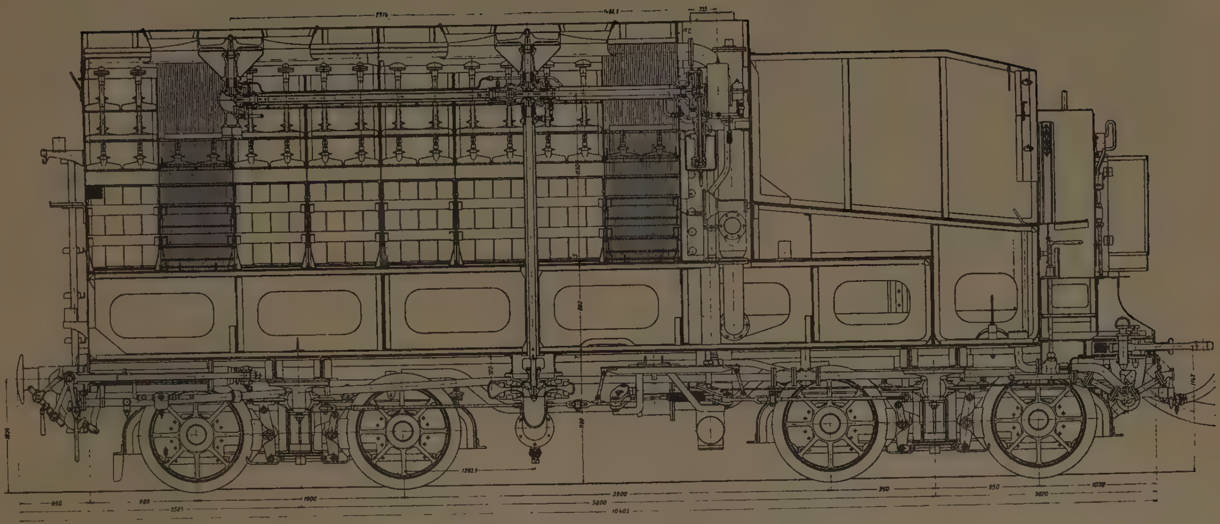


Fig. 16. — Tender: longitudinal section.

exhaust lead leading to the two condensers, which are on this engine placed side by side and not one behind the other, forms part of the smoke box support.

The auxiliary machines are grouped the condensate, feed and drain pumps composing a flywheel-less assembly. By means of a bye-pass valve on the feed pump it is possible to comply with delivery requirements. The auxiliaries which call for high speed, namely the fans and the cooling water pump are driven by a steam turbine installed on the tender behind the backwall of the coal space, while on the Krupp engine the circulating pump was placed on the engine.

Also the tender fans are distinct from Krupp's design by their being double and by the horizontal position of the blade wheels with vertical shafts, in the upper deck of the tender.

The cooling tender (fig. 16) resembles Krupp's in general appearance as also in its working, in that it cools by the evaporative method, the cooling water heated by passing through the condenser. The numerous metal cylinders packed in rows, which provided the cooling in the Krupp tender, are here replaced by closely packed perforated copper plates, between which air is drawn by the fans while the water in finely divided form and partly in the form of spray flows down over them from above.

The leading dimensions of the Maffei turbine locomotive in the form in which it was delivered are as follows :

Locomotive.

Steam pressure	22 at.	(313 lb.)
Diameter of driving wheels	1 750 mm.	(5 ft. 8 7/8 in.)
Diameter of leading wheels, bogie	850 —	(2 ft. 9 1/2 in.)
Diameter of trailing wheels, truck	1 206 —	(3 ft. 11 1/2 in.)
Average tractive force	11 000 kgr.	(24 250 lb.)
Heating surface of firebox	13.0 m²	(140 sq. ft.)
— — — tubes	146.7 —	(1 579 sq. ft.)
— — — superheater	51.0 —	(548.9 sq. ft.)
— — — total	210.7 —	(2 268 sq. ft.)
Grate area	3.5 —	(37.7 sq. ft.)
Weight empty	95.0 t.	(93.5 Engl. tons)
Adhesion weight	60.0 t.	(59 Engl. tons)
Running weight	104.0 t.	(102.4 Engl. tons)
Coupled wheel base	4 000 mm.	(13 ft. 1 1/2 in.)
Total wheel base	11 150 —	(36 ft. 7 in.)
Gauge	1 435 —	(4 ft. 8 1/2 in.)
To pass curve of minimum radius	180 m.	(9 chains)
Overall length	13 590 mm.	(44 ft. 7 in.)
Overall height	4 280 —	(14 ft. 1/2 in.)
Overall width	3 150 —	(10 ft. 4 in.)

Tender.

Water capacity for feed	4.3 m³	(945 British gallons)
Water capacity for cooling	20.0 —	(4 400 British gallons)
Coal capacity	6.0 t.	(5.9 Engl. tons)
Wheel diameter	1 000 mm.	(3 ft. 3 3/8 in.)
Total wheel base	7 700 —	(25 ft. 3 25/32 in.)
Overall length	10 545 —	(34 ft. 7 1/4 in.)
Overall width	3 100 —	(10 ft. 2 in.)
Weight empty	37.0 t.	(36.4 Engl. tons)
Weight running	68.0 t.	(66.8 Engl. tons)
Total wheel base engine and tender	20 890 mm.	(68 ft. 7 in.)
Overall length engine and tender	24 135 —	(79 ft. 2 1/8 in.)

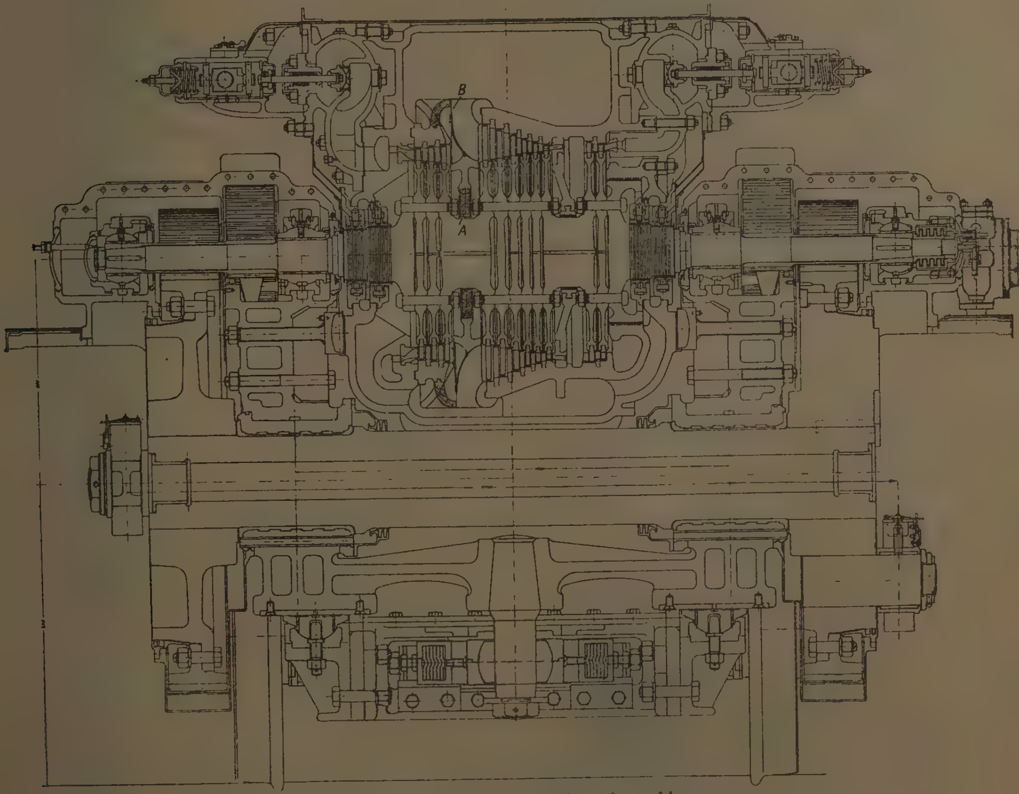


Fig. 17. — Section through main turbine.

3b. — Trials.

A large number of trial trips had already been run by the Maffei turbine locomotive on the Bavarian system of the States Railways and the engine had been for some time in regular service on the Berlin-Munich express trains between Munich and Nürnberg. The trials undertaken in the spring of 1929 with the aid of the dynamometer car nevertheless showed very high consumption results. In this case also it must be accepted that the reversing turbine in spite of its running in vacuum, led to considerable loss by fan action, with extremely high consumption in consequence, as without this drawback the Maffei engine with its higher pressure should have bettered the consumption figures reached by the Krupp engine, instead of which they were considerably above them. A partition was therefore fixed between the forward and the reversing turbine (see fig. 17) so that it was impossible for the exhaust steam from the forward turbine to blow into the reversing turbine and it was forced by the specially formed partition to take a pronouncedly radial path into the exhaust chamber. This partition had only one circumferential slit which served the smallest turbine as exhaust opening during travel in the rearward direction. While these alterations were being made a waste gas feed heater was fitted, and under these improved conditions the engine will be subjected to further tests.

4. — The exhaust turbine driven tender.

Brief mention has been made above of the interesting attempt which has been made with the exhaust turbine driven tender, to combine the good thermodynamic results given by the reciprocating locomotive in the realms of high pressure with the thermodynamic superiority of the steam turbine in the area of condensation. The Henschel Locomotive Company of Kassel had laid before the Reichsbahn an attractive proposal, to collect on their behalf, further information on the subject of turbine driven vehicles and the possibility of increasing the output of locomotives in connection with them, and this offer was accepted (fig. 18).

4a. — Description of the design.

The locomotive selected to be fitted with the steam tender is one of the numerous 4-6-0 superheated passenger locomotives. A waste gas suction fan driven by a turbine again serves to replace the exhaust pipe, though in addition as in the case of the Krupp engine, an auxiliary blower is provided in the chimey. The turbine can be supplied, through the medium of a two way valve, with either wet or superheated steam, and the same connection also serves the auxiliary turbine on the tender. When the regulator is open, the auxiliary turbines run on superheated steam. The exhaust passes into the exhaust feed heater as does that from the air brake pump. The boiler feed pump is installed on the tender and delivers the feed water from it through the feed heater; the condensate pump is also on the tender. The feed heater condensate is returned to the tank through an oil separator.

The exhaust from the locomotive cylinders is carried back through pipes carried on the footplate. A large oil separator is fixed in the pipe before it reaches the cab. Flexible couplings with telescope pipes lead the exhaust steam to the tender.

The turbine is naturally fitted on the tender with the condenser. *The steam supply of the turbine in the matter of quantity is automatically regulated by the operation of the usual reversing gear screw* (fig. 19). A servo-motor, operated by an exhaust pressure of 1.2 to 1.4 at. (17-21.3 lb. per sq. inch.) works a change over valve which, in accordance with the cut off of the reciprocating engine opens 1, 2, or 3 nozzles. The reversing turbine has only one steam lead : when running light the connection between the reciprocating engine and the turbine is entirely shut off so that entry of air to the turbine is prevented. An indicator on the end of the tender shows if the servo-motor is operating correctly.

The main forward turbine is a three-stage Zoelly turbine with a maximum revolution speed of 9 200 per minute; a single ring reversing turbine is fitted on the same shaft. The turbine drives the lay shaft carried in the frames through a double gear, the lay shaft being connected to the driving axles by crank gear. The tender has the 2-4-4 notation with the leading, driving and coupled axles carried in frames which are supported in the rear on a four-wheeled bogie.

The turbine exhaust flows through a short bend into the condenser which is of the evaporative-surface type and serves both for the condensing of the steam and the cooling of the circulating water. The steam is condensed in numerous bundles of brass tubes connected in parallel which are sprayed on the outside with the circulating water; the heat passes through the tube walls to the cooling water and is in turn taken up from the evaporating water by the air drawn through the condenser in the opposite

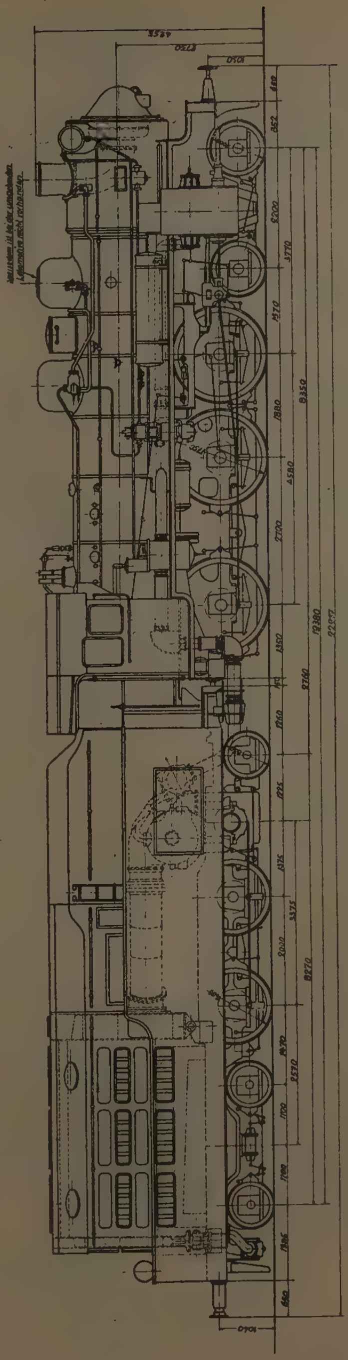


Fig. 18. — 4-6-0 passenger locomotive with 2-4-4 motor tender driven by exhaust steam

Explanation of German terms : Speisedom etc. = Feed dome does not exist on rebuilt locomotive.

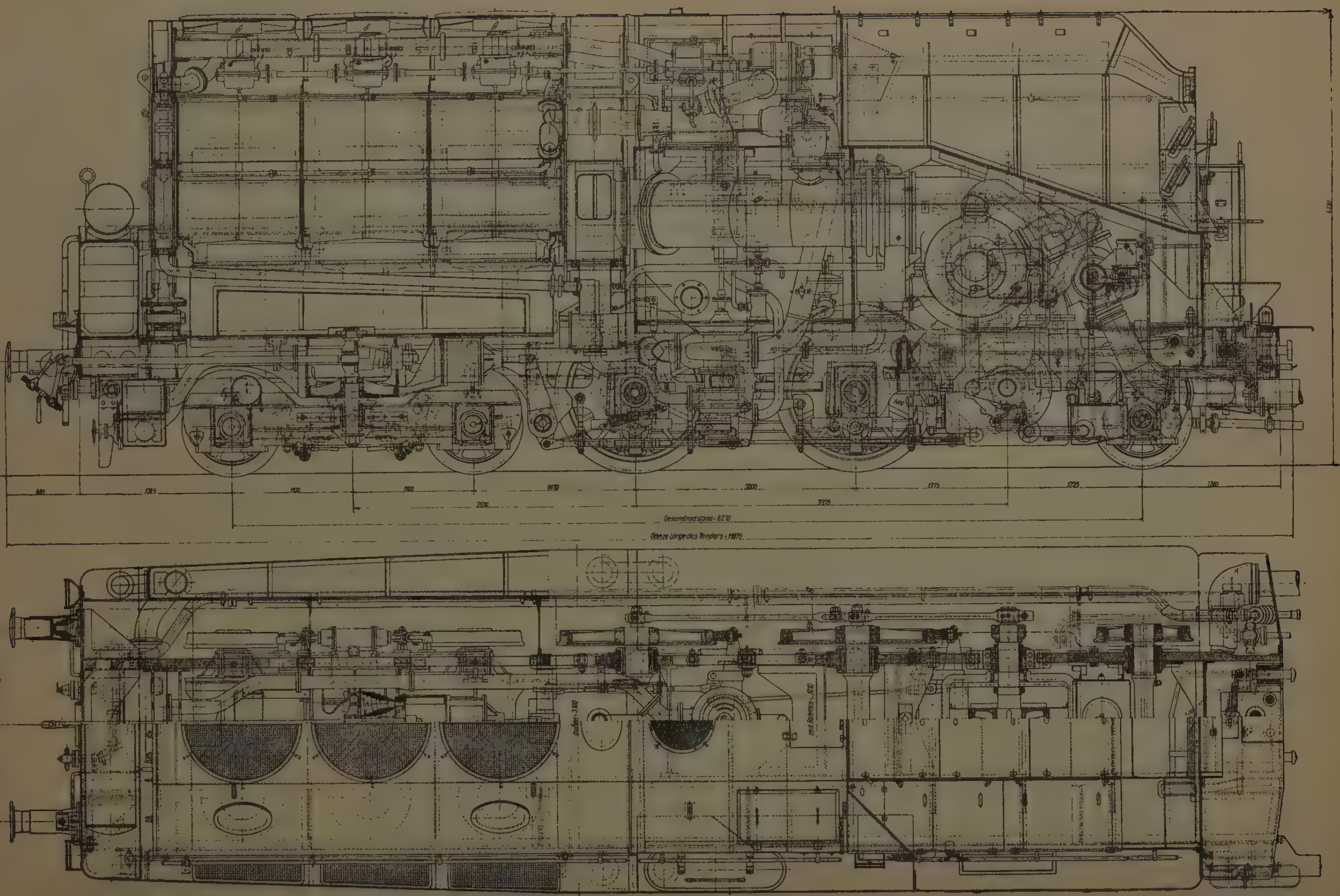


Fig. 19. — 2-4-4 motor tender driven by exhaust steam.

direction to the flow of the water. The spray water falling into the water tank is returned by the spray water pump into the circulating system. The condensate is collected in the condenser chamber and is passed thence to the feed pump.

The dimensions of the turbine driven tender locomotive are as follows :

Cylinder diameter	575 mm.	(22 5/8 inches)
Stroke	630 —	(24 3/8 inches)
Driving wheel diameter	1 750 —	(5 ft. 8 7/8 in.)
Carrying wheel diameter	1 000 —	(3 ft. 3 3/8 in.)
Steam pressure	12 kgr./cm²	(170.7 lb. per sq. inch.)
Grate area	2.62 m²	(28.2 sq. ft.)
Boiler heating surface, water side	146.28 —	(1 574 sq. ft.)
Superheater surface	58.9 —	(634 sq. ft.)
Adhesive weight	52.13 t.	(51.2 Engl. tons)
Running weight	79.5 t.	(78.2 Engl. tons)
Light weight	72.8 t.	(71.4 Engl. tons)
Fixed wheelbase	4 580 mm.	(15 ft. 5/16 in.)
Total wheelbase	8 350 —	(27 ft. 4 3/4 in.)
Tender driving wheel diameter	1 400 —	(4 ft. 7 1/8 in.)
Tender trailing wheel diameter	850 —	(2 ft. 9 1/2 in.)
Turbine revolutions per minute	9 200	...
Gear ratio : turbine to lay shaft	24.42	...
Condenser cooling area	279 m²	(3 003 sq. ft.)
Adhesive weight of tender	34.8 t.	(34.2 Engl. tons)
Running weight	84.6 t.	(83.1 Engl. tons)
Light weight	61.6 t.	(60.6 Engl. tons)
Fixed wheelbase of tender	4 600 mm.	(15 ft. 1 1/8 in.)
Total wheelbase of tender	8 270 —	(27 ft. 11 9/16 in.)
Fixed wheelbase of engine and tender	11 940 —	(39 ft. 2 in.)
Total wheelbase of engine and tender	19 380 —	(63 ft. 7 in.)
Overall length engine and tender	22 917 —	(75 ft. 2 1/4 in.)
Water capacity	16 m³	(3 520 British gallons)
Coal capacity	7 t.	(6.9 Engl. tons)

4b. — Trials with turbine tender.

One main result is to be obtained from the trial trips as shown in figure 20 for 80 km. (50 miles) per hour. While the abscissæ show the coal consumption the ordinates show the horse power at the draw hook for 1 : ∞ ; next to them is shown the curve for the 4-6-0 passenger locomotive with ordinary tender. This last curve begins with light running with 380 kgr. (838 lb.) per hour. The curve for the locomotive with turbine tender, on account of greater inherent resistance, attributable to the gear and the extra weight of the tender, as well as the consumption of the auxiliaries, begins with a coal consumption of 540 kgr. (1 190 lb.) per hour and for equal outputs up to 510 H. P. shows an increase of consumption over the normal engine. From this point on, the turbine tender engine is more economical and reaches with the steeply rising curve due to its greater heat gradient, its highest continuous output at 1 030 H. P. with an increase over the normal engine of 270 H. P. Slightly greater forcing is

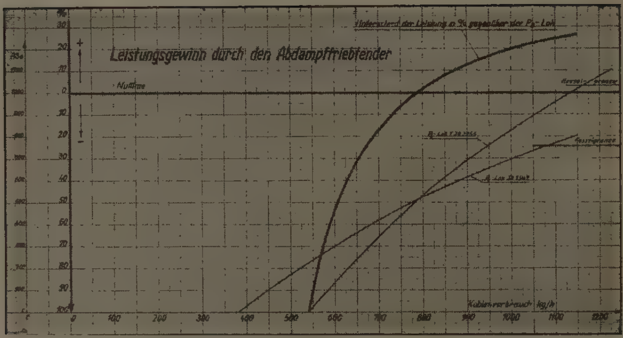


Fig. 20. — Difference in power at equal hourly coal consumption and at a speed of about 80 km. (50 miles) per hour.

Explanation of German terms : Unterschied, etc. = Difference in power in % as compared to P_8 locomotive. — Leistungsgewin, etc. = Supplement of power supplied by motor tender driven by exhaust steam.

permissable in the case of the scale free boiler of the turbine tender engine.

The heavy curve represents the difference in output in percentages as against the normal locomotive with similar coal consumption. The turbine tender is also at first less economical and only is superior in economy from 510 H. P. up to maximum output, when the saving is 25 %. In view of these facts, no one would seriously think of introducing the turbine tender in large numbers, seeing that coal economy with equal loads cannot be obtained throughout the whole service range of the machine and can only be bought by a much greater capital expenditure as well as increased maintenance cost. Nevertheless the trials have proved of educational value all the more as they were carried through without interruption.

The locomotive with its turbine tender has lately been in service in Kassel.

5. — **High pressure turbine locomotive.**

A proposal by Krupp for a turbine locomotive working at a pressure of 60 at. (853 lb.) is on paper; the reduced consumption figures hoped for from the improved design as compared with the turbine locomotive working at the hitherto usual pressures, are given in curve chart, figure 14.

The boldest proposal for a high pressure condensing locomotive is at present being elaborated by Maffei of Munich for the Reichsbahn. It concerns the development of the Benson principle for locomotives, under which the steam in the generator has the critical pressure of 225 at. (3 200 lb. per sq. inch) with a temperature of 375° C. (807° F.). The generator in which steam is raised from feed forced in at a pressure of 225 at. (3 200 lb. per sq. inch) without change in volume and without loss due to latent heat, must on account of the unusually high quality of the material, be kept entirely free from scale. The engine is intended to be condensing. It can therefore only be a turbine locomotive. Even when, in order that the steam shall not on account of the slightest drop in pressure, arrive at saturation condition, and when in order to obtain satisfactory action at the tur-

bine blades, a maximum pressure of « only » 180 at. (2 560 lb. per sq. inch) with high superheat is employed at the turbine, it is obvious that the temperature and pressure gradient from boiler to condenser is far too great to be handled in one turbine. The proposal therefore indicates two turbines with intermediate reheater, one high and one low pressure, which together transmit through intermediate gears to the lay shaft. As in this arrangement, two turbines are provided, and as the reversing turbine has previously caused certain constructional difficulties, a separate reversing turbine is fitted in a clever and comparatively simple manner, so as to reduce the loss of output due to fan effet. The hot tube fire box forms the rear portion of the boiler. The hot gases must naturally leave it at sufficient temperature so that a powerful current of hot gas will pass through the coils of tubes which must have a temperature of at the very least 375° C. (707° F.). This somewhat high temperature will be extracted from the waste gases on their way to the smoke box by means of the superheater and feed preheater interposed in their path. A waste gas feed water heater in the shape of a short boiler barrel section is supplied to heat the (circulating) feed. On account of the small storage capacity of the Benson boiler on the one hand, and on the other hand the very high output which is often demanded from the locomotive it is necessary to be able regulate the supply of heat to the boiler as quickly and as thoroughly as possible. On these grounds pulverised fuel firing seems to be peculiarly applicable to the Benson locomotive.

The locomotive appears on account of its simple appearance externally very like a normal 4-6-4 express locomotive.

III. — The high pressure reciprocating locomotive.

While in comparison with the normal locomotive, the turbine locomotive extends the heat gradient further *down* the scale, on account of lowering the pressure and temperature limits, the high pressure reciprocating locomotive does exactly the opposite. The boiler pressure goes entirely beyond the usual limits; it is in the first high pressure locomotive, so far built in Germany, after the designs of Schmidt-Henschel, of about 60 at. (853 lb. per sq. inch) in the case of the Löffler-Schwartzkopff engine, 120 at. (1 707 lb.). The engine built in Switzerland, to Winterthur designs has, as in the case of the Schmidt - Henschel locomotive, 60 at. (853 lb.) boiler pressure. All these locomotives exhaust to the atmosphere and have the great advantage of automatic and convenient provision of steam by the aid of the blast pipe; they have the simple trailing tender and are altogether cheaper than the turbine locomotive with its condenser. If into the bargain, the condensing tender were added the resulting high pressure turbine locomotive would achieve the largest imaginable heat gradient.

I. — The Schmidt-Henschel high pressure locomotive.

1a. — Design of the locomotive.

The high pressure locomotive has naturally a somewhat more complicated appearance than the normal reciprocating engine.

The stayed firebox cannot be used with the very greatly increased pressure. The special high pressure boiler can no longer be built as a rivetted boiler, but is made from a forged and machined steel drum. Dr. Schmidt whose great services in con-

nection with superheated steam are well known, has as the result of previous trials with a stationary boiler, developed the principle of a two-pressure boiler with indirect heating. In it the material is kept free from all strains which are not due to the steam pressure ruling in the high pressure boiler itself. It is also re-

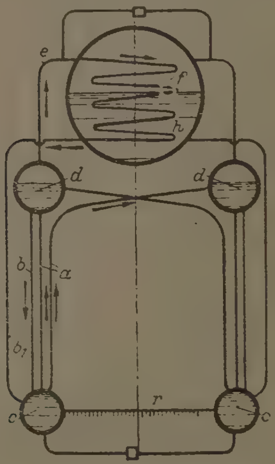


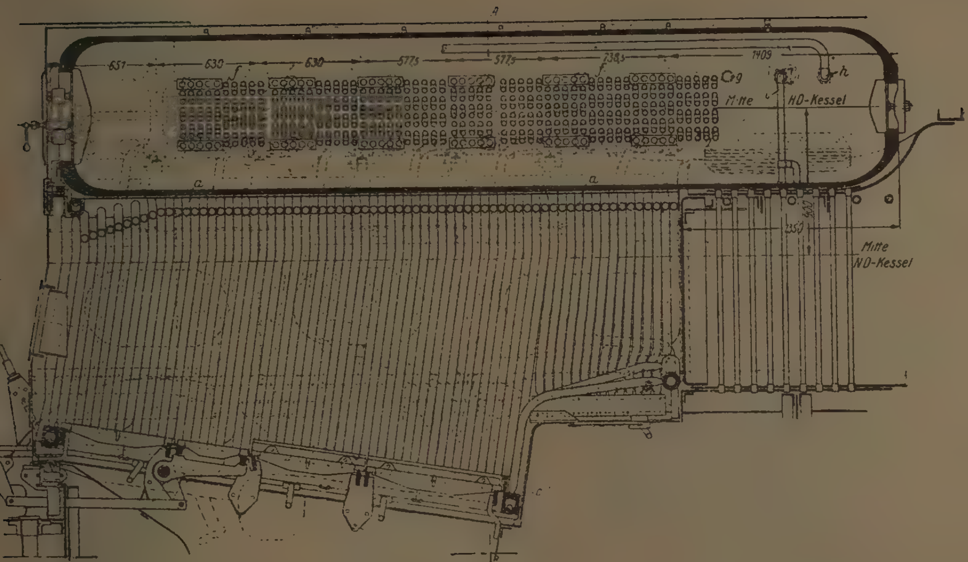
Abb. 21. — Schmidt-Henschel high pressure locomotive. — Diagram of heating and evaporating apparatus.

a = Up tubes. — b = Junction pipe. — b^1 = Down tubes. — c = Bottom header. — d = Top header. — e = Connexion tube to superheater. — f = Superheater tubes. — h = High pressure drum. — r = grate.

moved from all contact with the hot gasses which evoke additional and unequal stresses. In it the evaporation is in fact carried out by steam of higher pressure (90 at. = 1 280 lb. per sq. inch) which is passed through coils of tubes in the high pressure boiler. This hot tube system is supplied by a water tube firebox which is separate from the high pressure boiler itself. This firebox is not only heated by the flame but also by contact with the hot gases. The water tubes are so closely pitched over the grate that they protect the under side of the high pressure drum from the hot gases.

Figure 21 shows the arrangements of combustion and boiler layout. The actual high pressure container forms the upper part of the boiler, it contains a number of tube coils arranged in series of which f is one as is shown more clearly in figure 22. Steam at a pressure of 90 at. (1 280 lb. per sq. inch) enters this coil in a downward direction through the connecting tube e, transfers its heat and flows as condensed water through the down comer b_1 to the lower collector c. This lower collector which is in fact the foundation ring is bored from solid steel blocks. The high pressure water is again heated by the fire in the lower ascending pipe a and rises on both sides of the firebox r to the upper collectors d into which the system of cross tubes (marked with an arrow) which forms the roof protecting the high pressure drum, is secured. From this upper collector, which is bored from forged steel, the superheated steam again flows through e into the heating coils. The circuit is completed : b is like the other unlettered tubes, a circulating tube which ensures complete equilibrium of pressure through the system. The heating system is filled with scale free water and *in continuous circulation*, and, as no water is added from external sources, there is no formation of scale. Figures 22 and 23 show the arrangement of the high pressure boiler.

This high pressure boiler in which steam generation, delivery and feed proceed in the usual sense, must naturally also be kept equally free from scale. This important task is one that belongs to the low pressure boiler, in which a pressure of 14 at. (199 lb. per sq. inch) is maintained. The supply of water is so ar-



a to f : Same as fig. 21.
g Connexion with boiler feed valve.
h Drawing off of steam.
i Sludge extraction.
k Frame carrying boiler.
l Lateral guide of firebox.

Fig. 22. — Schmidt-Henschel high pressure locomotive.

Explanation of German terms : Mitte HD (ND) Kessel = Center line of H. P. (L. P.) boiler.

ranged that the whole of the feed for high pressure and low pressure steam including that for working the pumps, is pumped into the low pressure boiler. From the low pressure boiler, the proportion of water fixed for conversion into high pressure steam (60 % in the case of the first locomotive but more in future designs) is delivered into the high pressure drum where it flows over the heating coils and is evaporated. Now as the temperature in the low pressure boiler is considerably above that at which scale is heavily deposited on the plates of the normal low pressure boiler, scale forming matter is only carried into the high pressure drum with the feed in such small quantities that it forms a loose coating on the heating coils and can be washed off.

The low pressure boiler (fig. 24) is designed as an ordinary boiler barrel with regulator and feed domes, while at the back end it has a stayed recess into which the front end of the high pressure drum is seated. In other aspects it is similar to the barrel of a 4-6-0 three-cylinder express engine. *The low pressure feed pump* is of the Knorr-Nielebock preheater standard type which feeds through an exhaust preheater; the *high pressure feed pump* is also a direct compound, following the usual design, but the water cylinder is somewhat smaller while the steam cylinder is larger than in the normal de-

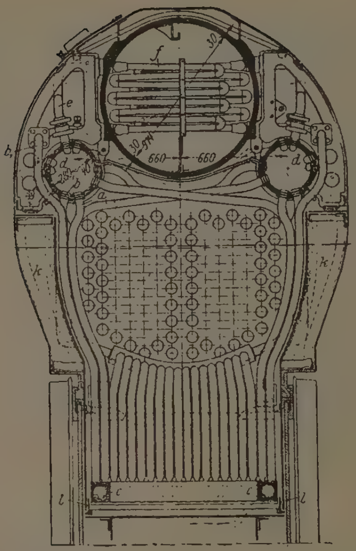
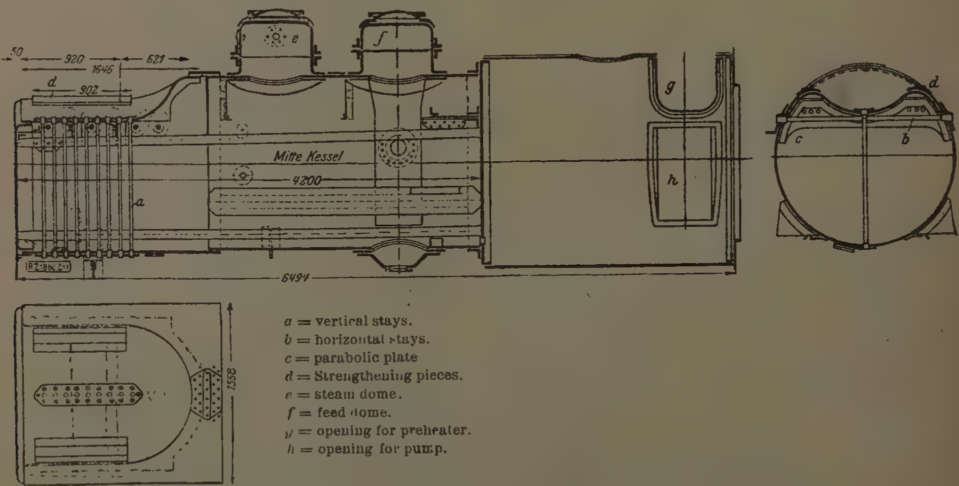


Fig. 23. — Schmidt-Henschel high pressure locomotive. (Section through firebox).

sign because of the very high feed pressure.

The *boiler mountings for the high pressure boiler* comprise two *high pressure feed valves* of comparatively small but strong construction, the valves and seatings being made of rustless steel *high pressure safety valves* of the same material, a hand operated *bye-pass valve* by which the excess of high pressure steam can be blown into the low pressure boiler and makes it possible to restrict the blowing to waste of the valuable high pressure steam of 60 at. (853 lb.) to the lowest possible limits. *Two high pressure water gauges* must be added; these consist of cast cases bored out and fitted with circular discs of Jena glass 20 mm. (25/32 inch) thick (fig. 25). These two gauges stand, as does the high pressure drum at such a height that to observe the water level the staff must mount a step and to make observation easier, a *so called lowered auxiliary gauge* is provided with the usual



a = vertical stays.
b = horizontal stays.
c = parabolic plate
d = Strengthening pieces.
e = steam dome.
f = feed dome.
g = opening for preheater.
h = opening for pump.

Abb. 24. — Schmidt-Henschel high pressure locomotive. — Low pressure boiler.

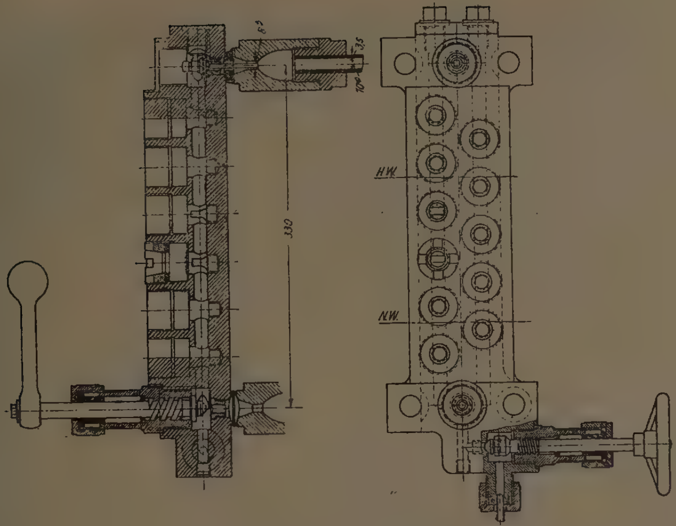


Fig. 25. – Schmidt-Henschel high pressure locomotive.
Water gauge for high pressure boiler.

type of glass to be opened and closed by hand and used in place of the proper gauge. The fireman is compensated for the increased work of observing the low pressure gauge (the low pressure boiler has of course also a water gauge) by the smaller amount of work with the shovel which he has to do as a result of the reduced consumption of coal. *A high pressure regulator* of the Wagner design completes the list of fittings; it is of this firms' new design and differs only from the normal regulator by its smaller size. There is a similar regulator for the low pressure steam supply in the low pressure dome and this is coupled to the high pressure so that there is only one lever for the driver to work as is the case of the normal locomotives.

In describing the superheater arrangement it is to be noted that owing to the high pressure of 60 at. (853 lb. per sq.

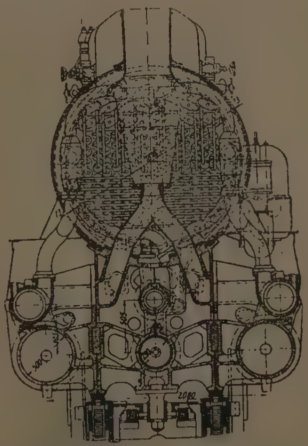


Fig. 26. — Schmidt-Henschel high pressure locomotive. (Cross section through smoke box and cylinders).

inch) a two-stage expansion as also a compound arrangement, was indicated. The steam after passage through the high pressure cylinder is reduced to between 10 and 14 at. (142 and 199 lb. per sq. inch) and is no longer highly superheated and so would therefore enter the zone of wet steam in passing to the outside cylinders. It would have been possible to superheat the steam a second time in an intermediate superheater but undesirable results were possible on account of oil residues from the high pressure cylinder lubrication. It was therefore arranged that low pressure steam heated in a low pressure superheater was mixed with the high pressure cylinder exhaust. The engine is therefore no longer a pure engine compound but one with fresh additional steam added at the receiver. The mixing of the steam is carried out by means of a mixing nozzle and the pressure in the low pressure boiler is the result of this combined steam pressure. As only approximately 60 % of the total steam used has to be supplied by the high pressure boiler it is necessary to employ two low pressure cylinders to utilize the expanded high pressure steam plus the above mentioned additional low pressure steam, so that the three-cylinder type of engine was obviously called for.

The superheaters are of the small tube type and are installed in the low pressure boiler with the low pressure heater lying above the high pressure heater. The boiler contains smoke tubes only and these are fitted with heater tubes as shown in figure 26.

The high pressure cylinder, 290 mm. (11 7/16 inches) has peculiar means of steam distribution. This is provided by a small piston valve which gives the same cut off as that for the outside cylinders; it is connected with the outside gearing so that there is no added complication in this arrangement. No special arrangements are called for starting since the outside cylinders receive the additional steam as explained above. Except for the extra water and steam gauges the drivers cab presents the usual appearance.

Figure 27 shows the elevation of the high pressure locomotive. The principal dimensions are as follows :

Diameter of high pressure cylinder	290 mm.	(11 7/16 inches)
Diameter of low pressure cylinder	2 × 500 —	(19 11/16 inches)
Stroke-volume ratio		1 : 6.5
Driving wheel diameter.	1 980 mm.	(6 ft. 6 in.)
Carrying wheel diameter	1 000 —	(3 ft. 3 3/8 in.)
Fixed wheelbase	4 700 mm.	(15 ft. 5 in.)
Total wheelbase	9 150 —	(30 ft. 1/4 in.)
High pressure boiler :		
Boiler pressure.	60 at.	(853 lb.)
Heating surface of generator coils in high pressure drum (outer side)	20.23 m²	(218 sq. ft.)
High pressure drum (outer side)	39.6 —	(426 sq. ft.)
High pressure drum, length	5 161 mm.	(16 ft. 11 3/16 in.)
High pressure drum, inside diameter	914 —	(3 inches)
Water content at low level	1.76 m³	(87 British gallons)
Area of evaporating surface	2.64 m²	(28.4 sq. ft.)
Heating surface of high pressure superheater.	40 —	(430 sq. ft.)
Boiler pressure (in L. P. boiler)	14 at.	(199 lb. per sq. inch)

Diameter of boiler	1 600 mm.	(5 ft. 3 in.)
Heating surface (fire side)	117.6 m²	(1 266 sq. ft.)
Heating surface of low pressure superheater.	39.6 —	(426 sq. ft.)
Grate area	2.47 —	(26.6 sq. ft.)
Heating surface of low pressure superheater .	13.6 —	(146 sq. ft.)
Overall length of engine (over buffers), in-		
Adhesive weight	21 200 mm.	(69 ft. 6 11/16 in.)
Adhesion weight	60 190 kgr.	(132 700 lb.)
Light weight	85 620 —	(188 760 lb.)
Running weight	92 080 —	(203 000 lb.)
Tender :		
Wheel diameter	1 000 mm.	(3 ft. 3 3/8 in.)
Total wheelbase	5 600 —	(18 ft. 4 1/2 in.)
Water capacity	31.5 m³	(6 930 British gallons)
Coal capacity	7 000 kgr.	(6.9 tons)
Light weight	28 120 —	(62 000 lb.)
Running weight	66 620 —	(146 870 lb.)

1b. — The trials.

The engine was in the first instance delivered with the water tube firebox made up of six separate elements, each consisting of water tubes connected to the foundation ring (not divided at first) and to header. The first trials with the dynamotor car took place with the engine as delivered, in February and March 1927, on the line between Wildpark and Magdeburg and later between Wildpark and Kothen. The very level character of this section was desirable for the even running speed trials, as the system of testing with an engine behind the train engine, acting as a brake, had not at that time been developed. The time table called for an average through speed of 80 km. (50 miles) per hour, but to provide for the time required to attain steady running speed, for the braking time as well as for the extra time allowed for climbing the bank between Burg and Magdeburg and the service slacks, a speed of about 90 km. (55.9 miles) per hour was necessary.

The question of the indirect heating of the high pressure boiler was naturally of great interest. The pressure in the various heating elements proved to be very uneven and was constantly highest in element 4, that element being not only situated in the center of the radiation zone but also most exposed to the passage of the flame in the neighbourhood of the brick arch. The heating elements were and are proportioned to carry a working pressure of 90 at. (1 280 lb. per sq. inch) and the pressure in No. 4 element always exceeded this figure during heavy demands on the engine; in spite of this excess of pressure the desired 60 at. (853 lb.) working pressure was not reached. A higher average pressure than 54.3 at. (772 lb. per sq. in.) in the high pressure boiler was not reached.

The highest sustained power reached, *viz.* 1 355 effective H. P., showed the capacity of the water tube firebox to absorb and transmit a very great amount of heat in spite of the very small temperature differences. The firebox surface exposed to radiant and contact heat was only 20.2 m² (217 sq. feet) but this area absorbed, during the hardest runs, sufficient heat to generate per hour 238 kgr. of high pressure steam per sq. metre

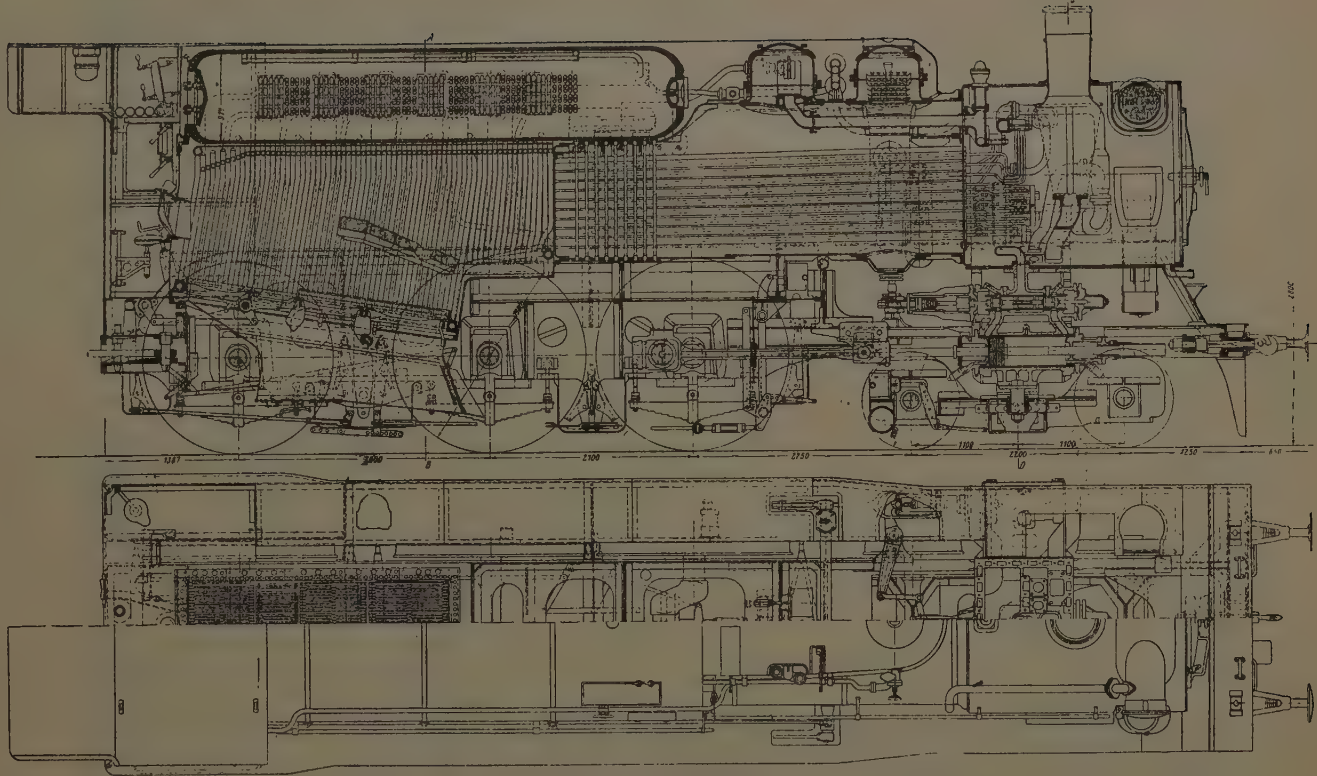


Fig. 27. — Schmidt-Henschel high pressure locomotive (Longitudinal section).

(48 lb. per sq. foot) of heating surface and 255 kgr. (52.2 lb. per sq. foot) during the time the engine was running under steam. Under these conditions, the difference in temperature between the high pressure boiler and the average of the 6 heating elements was only 37° C. (66.6° F.). At lower boiler output *viz.:* about 150 kgr/m²h. (30.7 lb. per sq. foot per hour) the temperature difference fell to 22° C. (39° F.).

The trials as a matter of fact led to the conclusion which was established later, that a subdivision of the water tube firebox into separate elements is not permissible, because full utilization of the high pressure working system is prevented by consideration for the hardest worked element. This last result gave the impetus towards the decision to rebuild the water tube firebox as an undivided system.

Coal consumption reached its lowest point in these first trials at 1.06 kgr. (2.33 lb.) per H.P. hour using good Silesian coal with a heat content of 7 090 kgr./cal. (12 760 B. T. U. per lb.) which represents an improved *heat consumption* of 7 500 kgr./cal. (13 500 B. T. U. per lb.) at the draw hook. The total coal consumption went hand in hand with the satisfactory heat consumption in the steam (from 0° C.) of 5 600 kgr./cal. 10 080 B. T. U. per lb.) per horse power-hour and represented a saving of from 7 to 12 % as compared with a very good normal locomotive.

The proportion of high pressure steam to the total was 64 % at low load and at high load, or 1 355 H. P., it fell to 55 %. If the steam for the pumps which is taken from the low pressure system is included the percentage of high pressure steam will be somewhat lower by about 4.5 % and the percentage at low loads will be 59.5 %.

The *boiler efficiency* with a coal consumption of about 250 kgr./m² (55 lb. per sq. foot) per hour representing 500 H.P. was 70 % with the maximum output of 1 355 H.P. representing 600 kgr./m² (132 lb. per sq. foot) per hour, the efficiency was 62.5 % or rather below that of a good, new normal boiler.

The first trials therefore gave pleasant promise for an initial test although it is understandable that some small troubles were met with during the trials. The labour of firing was not heavier than for a normal boiler. The fireman has certainly two boilers to feed, in which work he is assisted by the provision of the auxiliary water gauge. The driver seeing that the high pressure and low pressure regulators are coupled and that there is only one reversing screw to be operated, has little more to do than with the normal engine. As in the case of this engine the blast pipe is present to provide the automatic regulation of the generation of steam to meet consumption, it can be said that as a result of the first trials there is little difference from the working of an ordinary locomotive and there is no hardship entailed on the staff.

After the trials the engine was returned to the builders for the purpose of rebuilding the water tube firebox and other alterations. *Trials of the altered engine were recommenced in the middle of February 1928.*

After a few trial trips in front of trains made up of express train coaches, trials started on the 6th of March and continued till the 30th of that month, on the line between Berlin and Magdeburg, using the engine which had in the meantime been fitted with the Riggenbach

brake, as load coupled directly behind the dynamometer car.

The most important conclusions reached in this new series of tests *was that the desired maximum pressure of 60 at.* (853 lb. per sq. inch) *was now fully or nearly attainable.* The col consumption per H.P. at the drawbar differed very little at low loads from the figures of the previous year's trials but the lower limits of the consumption curve on this occasion touched 0.98 kgr. (2.16 lb.) per effective H.P. hour while in the previous trials, the best result obtained (based on coal of 7 000 kgr./cal./kgr.) (12 600 B. T. U. per lb.) was 1.07 kgr. (2.35 lb.)

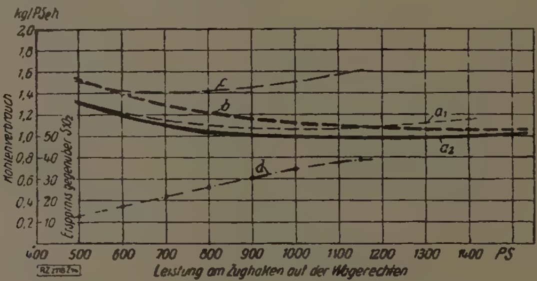


Fig. 28. — Coal consumption per effective horse power-hour at drawbar hook [speed about 80 km. (50 miles per hour)]. Calorific value of coal about 12 600 B. T. U. per lb.).

a_1 Coal consumption of high pressure locomotive in 1927.
a_2 " " " 1928.
b " of Bavarian S 3/6 4-cylinder express locomotive.
c " of S 10^2 3 cylinder express locomotive.
d Economy with high pressure locomotive (1928 consumption) compared to S 10^2 locomotive.

Explanation of German terms : Kohlenverbrauch = Coal consumption. Ersparnis gegenüber S 10^2 = Economy compared to S 10^2. — Leistung am Zughaken auf der Wagerechten = Power developed at drawbar hook on the level.

per effective H.P. hour. The heat of combustion is therefore, as a result of the alteration to the engine, better utilized to the extent of about 8 %. For purposes of comparison the consumption curve of the last built locomotive of the former Bavarian State Railways, the S 3/6 four-cylinder compound, is included (fig. 28), this engine having been tested with the brake approximately the same as the high pressure locomotive and having shown itself an extraordinarily economical machine. The lower limit of her consumption curve compares with that for the first trials of the high pressure locomotive so that the very economical normal engine is under cut in the matter of coal consumption by about 8 %.

A better comparison to show the thermal progress made, would be one made with an earlier original type of normal engine with a pressure of 14 at. (199 lb. per sq. inch). Such a consumption curve is given being repeated from the earlier details of tests available, which, with 700 H.P. at the drawbar shows a mini-

mum coal consumption figure of 1.4 kgr. (3.08 lb.) per H.P. hour as against the present figure of 0.98 kgr. (2.16 lb.) at 1 150 H.P. and also a coal saving of about 30 %. This saving which increases with increasing load, has an approximate average value of 25 % so that when the high pressure locomotive is loaded to the maximum the saving will be increased.

At an output of 600 H. P. the high pressure cylinder provides approximately 35 % of the total power; this proportion sinks at high outputs to about 30 % so that the division of work is good.

The *third series of trials* with the new evaporating elements of more suitable material, altered form and 22.3 m^2 (240 sq. feet) contact surface on the steam side in the high pressure boiler, were carried out between January and April 1929 on the Berlin-Magdeburg line, using the brake locomotive as load; it was only necessary to add express train coaches to the train when very heavy loads were required. The speed was no longer restricted to 80 km. (50 miles) per hour trips being also run at 60 and 100 km. (37.3 and 62 miles) per hour. The proportion of high pressure steam to the total steam consumption (steam for pumps included), varied more than in the first trials; the proportion was however fairly well kept up, being higher at low outputs. From 70 % with the engine running light, the proportion frequently fell to 50 %, the 50 % generally corresponding to the heavy loads.

The steam and coal consumption, excluding steam for air pump, on this occasion showed higher values than in the previous years trials. The division of output as between the cylinders was again that desired, the high pressure cylinder giving one third of the total. The boiler efficiency curve, which fell sharply in sympathy with increasing load ($n = 0.75$ at 5 500 kgr. [12 125 lb.] steam per hour to 0.6 at 11 500 kgr. [25 350 lb.] steam per hour) showed that the new evaporating elements had already reached the low limits as regards their heating surface.

For a *fourth series of trials*, the results of which are not as yet fully worked out, one extra tube element was added to each individual evaporator element. From such partial results as have already been got out it appears that an undoubted saving of coal consumption at the higher outputs has been obtained as compared with the second series of trials in 1928. The locomotive will shortly be put on express service under the Reichsbahn Authorities in the Kassel Division (fig. 29).

On the completion of all these trials two statements can be made : The first, that the system of indirect heating has throughout proved rich in results. Secondly, that the thermal results given by this first high pressure locomotive — expressed in a saving of 8 % of coal — are taken as a whole, *economically* too small to justify the complicated design of the high pressure locomotive in its present form. The reason that greater economy was not obtained, lies ready to hand. It is to be found in the fact that the proportion of high pressure steam from which alone the thermal improvement can be obtained, is especially at high output only approximately one half of the total steam used. *If it is desired to render a high pressure locomotive of similar type more economical, the proportion of high pressure steam used must be considerably increased.*

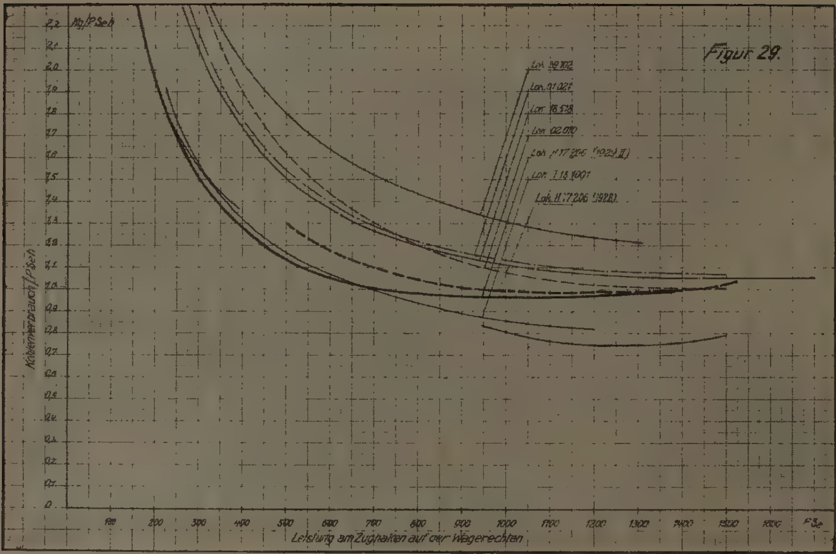


Fig. 29. — High pressure locomotive compared to locomotives of other types.
Coal consumption per effective horse power-hour at a speed of 80 km. (50 miles) per hour.
Calorific value of coal 12 600 B. T. U. per lb.

Ordinate = Coal consumption in kgr. per effective horse power-hour. — Abscissa = Effective horse power developed at drawbar hook on the level.

1c. — New proposals along Schmidt-Henschel lines.

Two proposals by which the proportion of high pressure steam used shall be increased to between 80 and 100 % of the total, are already being worked out. At medium loads the engine will work entirely with high pressure steam and only at high loads will a proportion of low pressure steam be added. The basic design of the boiler remains unaltered, though the indirectly heated high pressure boiler with its water tube firebox is considerably larger, while the low pressure boiler, which sinks almost to the level of a preheater, though it still continues to provide for the prevention of scale, becomes smaller. In consequence of the very minor role played by the low pressure boiler, the engine itself will become a pure compound machine, and the inter-superheater which was dispensed with owing to the solution provided for reheating by the admixture of highly heated high pressure steam, as before described, will resume its proper functions. The two proposals mentioned above differ in accordance with the way this inter-superheater is used, either as a heat exchanger with highly superheated steam, or as a pure inter-superheater with an efficient oil separator placed in front of it, and concern on this occasion,

not the alteration of an existing engine but an entirely new design. On this account the choice of the type of locomotive to be buit, has fallen on the 4-6-2 four cylinder compound class which is capable of high output, and the engine is designated as competitrix of the Reichsbahn simple express locomotive.

2. — The Löffler-Schwartzkopff high pressure locomotive.

While the engines mentioned above are as yet only in the proposal stage, the *Löffler-Schwartzkopff 4-6-2 high pressure express locomotive* intended for the Reichsbahn, is nearing completion in the works of the Berliner Maschinenbau Company (formerly L. Schwartzkopff).

The peculiarity of the Löffler high pressure locomotive, which originated in the Vienna Locomotive works at Floridsdorf lies, as is known, in the evoporation of water in a high pressure boiler by means of steam of equal pressure and high superheat which is blown into it. The high pressure boiler is therefore free from any actual connection with the firebox and can be placed in any suitable position on the engine frame, which is a great advantage. The steam generated in the high pressure boiler is drawn off by a steam circulating pump and is forced into the superheater which takes the form of a species of water tube firebox. The greater part of the steam which has been highly heated in this system of tubes is again passed as superheated steam through an inlet into the high pressure boiler, the remainder is utilized to provide the working steam for the locomotive. After it has been condensed by means not as yet decided on, it is again returned to the high pressure boiler by the feed pump, so that it forms a simple circulation of water and steam, and the principle of keeping the high pressure system free from scale in maintained. The driving motor of the circulating pump merely has to overcome the loss due to friction and flow resistance of the steam stream; in order therefore that the pump shall not on account of its output become unwieldy, it is necessary that the steam shall have a very small specific volume. This can only be the case with very high pressures, so that the Löffler system can only be worth while with pressures from 100 at. (1 422 lb. per sq. inch) and above. A pressure of 120 at. (1 707 lb.) has been chosen for this particular engine. The circulating is designed as a three-cylinder steam driven flywheel pump, while later it was proposed to drive the pump mechanically from the engine. On account of the great importance of the role played by the circulating pump it is installed in duplicate.

In the Löffler engine the condenser is at the same time the low pressure boiler for driving the low pressure engine. As only low pressures are dealt with in this boiler, scale free water is not necessary and the expanded steam is released to atmosphere through the blast pipe. The Löffler engine is therefore an open exhaust machine with a simple trailing tender. The condenser which serves as the low pressure boiler is placed in front of the smokebox, and a low pressure superheater and an air heater are arranged between it and the superheater system for utilizing the heat of the hot gases.

The engine is a three-cylinder machine with two outside high pressure and a single low pressure cylinder between the frames, so that it is not actually a pure compound engine. The builders estimate on a saving of 45 % of coal as com-

pared with a good normal engine with open exhaust.

A sketch of the engine is shown in figure 30.

IV. — Diesel locomotives.

1. — History and investigations.

The leanings of the Reichsbahn towards the Diesel engine are of comparatively old date. The first Diesel locomotive ever built, was tested by one of the predecessors of the Reichsbahn, to wit the Prussian State Railways, in 1913-1914.

This engine was a (4-4-4) express passenger engine, the engine portion for which was built by Borsig while the Diesel motor was supplied by Sulzer. The four-cylinder Diesel motor was of V type and was installed in the center of the chassis; it drove a lay shaft below it which was coupled to the two driving axles by connecting rods. *It was therefore an engine with direct drive.* Starting could not naturally be carried out by the Diesel process as this calls for a minimum number of revolutions before the adiabatically compressed air is of a sufficiently high temperature to ignite the oil spray. The starting of the engine with its train was therefore carried out by compressed air; this air was provided by a separate compressor driven by a small Diesel motor and served exclusivey to work up speed to about 25 km. (15.5 miles) per hour so that the speed should be sufficient to permit the Diesel motor to take up its work on the Diesel process. In spite of this the starting power of the locomotive was so small and operation so difficult that nothing came of the experiment. This experience taught the drastic lesson that the Diesel engine *alone* was not suited for *direct* drive on a locomotive which must always start against load, much as direct drive was to be desired in the interests of simplicity and cheapness.

The interest in Diesel vehicles however was not on that account dropped in Germany but found a second development in the shape of a *Diesel-electric coach* built by the then Saxon State Railways.

In this instance the difficulties in starting were overcome as the Diesel motor with its generator could be started *before* the train was required to start and could provide a considerable starting effort.

At the beginning of the twentieth year of this century as a result of increased appreciation of the necessity for heat economy, the effort to adapt the highly economical internal combustion Diesel motor for locomotive work was again revived. The intention to build an engine of large type first came to head in Russia, as one of the oil producing countries. The connection of Germany with this effort came about from the fact that the contract for the construction of the locomotive was placed in Germany (the locomotive portion being placed with the Hohenzollern Works and the Diesel motor with the Augsburg-Nürnberg Company [M. A. N.]) and the Reichsbahn became in a position to be present at running trials made on a specially constructed set of test rollers which were fitted with brakes. The acceptance tests to be made on the Russian lines also provided opportunities for attendance. The engine concerned was a *Diesel-electric machine* of the 2-10-2 type, the individual axles being driven by motors carried on bracketted bearings. In this case also as in the case of the motor coach mentioned above, starting difficulties did not appear and good regulation of tractive power and speed were easily possible, although they were purchased at the expense of an ex-

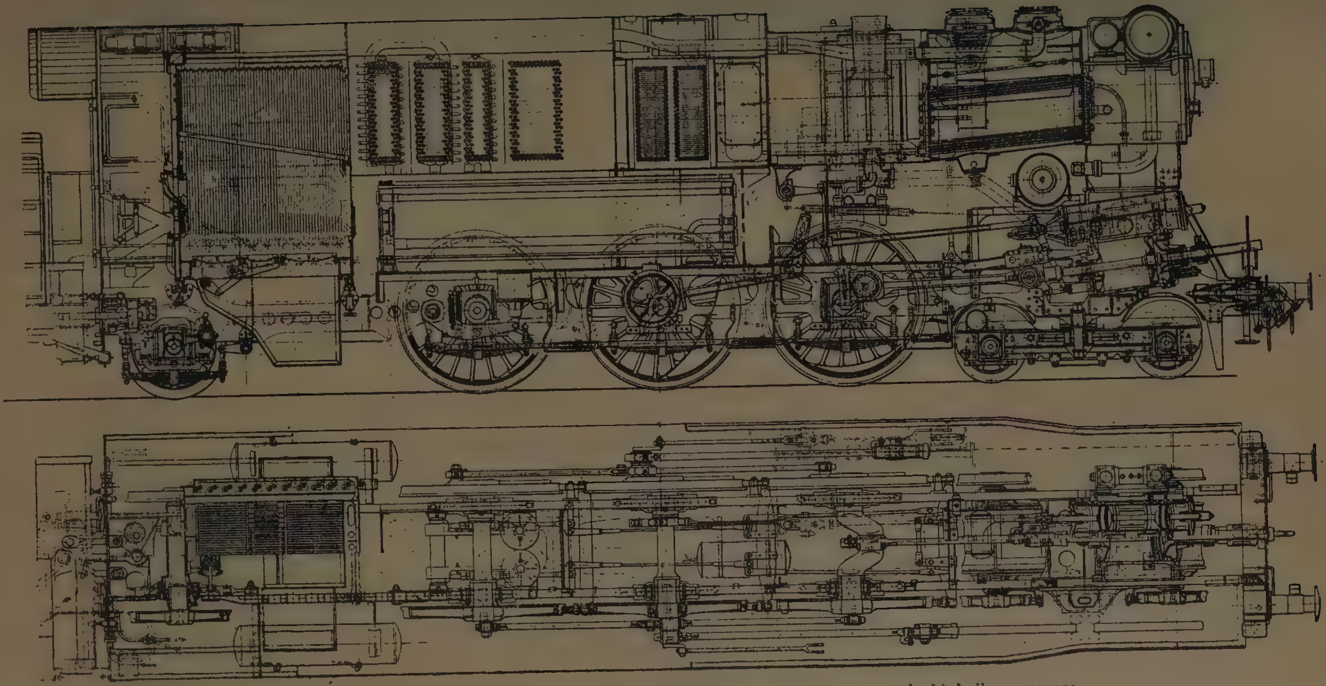


Fig. 30. — Löffler-Schwartzkopff type locomotive with 120-at. (1707 lb. per sq. inch) boiler pressure.

pensive and complicated machine. It may be said at once that the trials gave the result that had been anticipated. The total useful output at the motor shaft was between 32 and 35 % from which the comparatively small electric transmission losses (less wiring losses) had to be deducted, with the result that the thermal efficiency at the tyre represented 27 %. Only air resistance and journal friction therefore still remained to be deducted, of which the former would be of small amount at goods train speeds, so that a final total useful output of 25 % at the draw hook could be counted on.

Some time before participating in the trials of the Russian locomotive, the Reichsbahn had occasion, in the early part of 1924, to investigate by means of accurate measurements with their dynamometer car, a small Diesel locomotive, which the Görlitz Maschinenbauanstalt had built up of existing suitable machine parts, for the study of the Diesel locomotive question. In contrast to the transmission systems used for the engines previously mentioned, this locomotive was designed for pressure gas transmission (pneumatic) in which the Diesel motor drove a compressor, the compressed gas from which was utilized to work an ordinary locomotive mechanism. Exhaust gas from the Diesel motor was chosen in preference to pure air in order to prevent the possibility of the explosion of a combination of oil residue and oxygen from the air. The motor was a four-stroke engine of 100 effective H. P. such as are used for ships' launches of the larger types; the output of the complete locomotive was comparatively small (about 35.9 H. P.).

In view of this small output and because of the makeshift nature of the machine, which at most could only demonstrate the practicability of the system, no great thermal efficiency could be expected, and this was restricted to about 9.5 % at the draw hook.

The basic idea however showed itself capable of giving results; the controlability, which was equal to that of a steam locomotive, was good, and was obtained by means of the locomotive valve mechanism and the bye-pass of the compressor which latter played the role of the engine regulator. There was no difficulty over starting as the Diesel motor and compressor could be run up before the train had to be started.

2. — Diesel locomotive with hydraulic transmission.

About that time (1924) the various firms interested in the Diesel locomotive commenced very active investigations on the subject of the use of hydraulic, or as it should more properly be called, oil pressure transmission. Of these firms, the Linke-Hoffman Works of Breslau came to the front with a locomotive of 120 H. P. which they had built for shunting in their own works.

In the so-called *hydraulic transmission by oil pressure*, the Diesel motor is started while the pressure oil pump remains at rest; power is generated by bringing into use the secondary system which acts as the motor and regulation is effected by the variation of the subdivided secondary driving system.

The advantage of being able to install the Diesel unit independently of the machinery which drives the locomotive wheels, which in practice results in the installation of that unit longitudinally in the engine housing, applies also to some extent to the hydraulic transmission, as it permits of undoubted freedom in the re-

lative positions of the Diesel engine and the oil motor.

The hydraulic system of transmission is being very carefully studied on a trial locomotive in addition to a locomotive of smaller dimensions which has been ordered by the Reichsbahn.

There are at present under test :

1. One small two-axle Diesel motor locomotive, fitted with a Diesel motor made by the Mannheim Motorwerke which is for use as a very light shunting engine;

2. One six-coupled engine with axle notation C, built by Henschel und Sohn, of Kassel, and the Gasmotoren-Fabrik, of Deutz, and fitted with an airless injection motor;

3. One C-1 type locomotive by the Linke-Hoffman Works of Breslau;

4. One 1-B Diesel motor locomotive built by the Motor-Lokomotiven-Verkaufsgesellschaft of Baden.

The reports on the trials made with these locomotives can be summarised in a few words because the results of all of them have been alike, in that the efficiency of the hydraulic transmission in the shape of the Lentz gear, has not reached the pitch demanded by the Reichsbahn. The *appreciably higher capital cost* of the Diesel as compared with the steam locomotive of equal power is not the only deciding factor; there is also the cost of the heat unit. For a smaller consumption of calories per horse power can be financially outweighed and may even be nullified if the cost of the calorie obtained from oil costs many times that from coal, in other words when the *price to be paid for power* is greater than that of the comparable steam locomotive. In Germany for instance gas oil costs three and a half times as much as coal.

The good points of the Diesel locomotive cannot compensate for such a basic drawback. If one attributes to the Diesel engine a total thermal efficiency at the shaft of 32 to 35 % and demands an efficiency, between the shaft and the draw hook at low speeds, of at least 0.7 or over, then, if the locomotive design is to be represented as economical, the efficiency obtained at the draw hook, must be at least 22.4 %.

As against this figure, the small 4 coupled locomotive (160 H. P. motor) only gave a thermal efficiency of from 10 to 15 % depending on the load and which of the three gears was used, a result which found an analogy in the high fuel consumption which at best fell to 425 gr. (0.94 lb.) per H. P. at the draw hook. The larger Henschel-Deutz locomotive (300 H. P. motor) reached with each of its two main change ratios a maximum total efficiency of from 15 to 17.5 % and, though the transmission efficiency was somewhat better, it did not reach the figure demanded. The 1-C Linke-Hoffman engine also showed no better result in the matter of thermal efficiency as it did not exceed 17.5 % on fourth or fifth gear and, on third, did not exceed 15 %. A heat flow chart was worked out from indicator digram taken during the best run. The motor utilized 42.2 % of the heat content of the fuel, but at the modest speed of 23 km. (14.3 miles) per hour, unhampered by any noteworthy air resistances, only 17.5 % of the heat came to light as effective output. The effective drawbar hook output represented only 42 % of the indicated output, while the steam locomotive shows a comparative figure of 90 %; it must also be remembered that the internal resistance of the 4-stroke Diesel motor is very much greater than that of the double acting steam engine.

The smaller 1-B Mannheim engine (250-H. P. motor) also showed a total

efficiency of between 10 to 16.8 % with not less than two thirds of full load.

The net result of all these trials of fluid transmission which the Reichsbahn undertook with great expectations, because there was something attractive in them, was in all cases an unexpectedly low efficiency in the transmission for motor to lay shaft. The Lentz transmission wavers between the Scylla of an unsatisfactory volumetric efficiency, which was shown by the tests to be below 50 % and the Charybdis of very high working friction because of the close spacing of the pump vanes. This results in high oil temperature and the use of more power for running the blower to carry off the heat. Designs had already been prepared for building a 1 000-H. P. Diesel locomotive, which was the largest size believed possible with the Lentz gear, but were not proceeded with.

3. — The Diesel locomotive with gear transmission.

The Reichsbahn had proved in the course of several test runs it was able to make with the second Russian Diesel locomotive — an engine of the 1 E 2 type with toothed gear transmission — that the improvement in the gear transmission for larger locomotives, at one time only hoped for, might actually be achieved. In this locomotive the power from the motor is transmitted to the lay shaft by Krupp high grade triple toothed gear. The engagement of the various gears is effected by magnetic couplings. This locomotive working with medium and heavy loads at an even sustained speed has an efficiency calculated at the draw hook of 24.1 to 29.4 %. As was to be expected the high class toothed gearing at its best gave even better results than electric transmission. One disadvantage — at least in the view of the Reichsbahn — is the restricted graduation of power on account of there being three gear ratios, which causes too great a deviation from the usual tractive effort hyperbola as a function of the speed. At the higher speeds the proportion of output as compared with weight, was very much less than for the steam locomotive of equal dimensions, even when the tender was taken into consideration. With a view to high efficiency, the Reichsbahn had under consideration a proposal for a gear transmission with an increased number of changes, but the idea was eventually given up on account of too great complication.

4. — The Diesel locomotive with air pressure transmission.

In 1924 the Esslingen Lokomotivfabrik, in conjunction with the Augsburg-Nürnberg Maschinenfabrik (M. A. N.) were given a contract by the Reichsbahn for a *2 C 2 Diesel locomotive with air pressure transmission.* The gas pressure transmission provided the same easy control by regulator and distributing gear as gave satisfaction in the case of the primitive Görlitz experimental machine. Frankly this system gives inferior results to both toothed gear and electric transmission. This was to be expected after the results of the trials with the small Görlitz assembly had been seen, because the efficiency of the compressor itself is less than that of a steam engine, and the efficiency figure for the machinery driving the wheels has to be added to that of the compressor unit. If however the heat in the exhaust gas, which is usually lost is utilized to still further considerably increase the temperature, by means of an *air heater*, we may expect to obtain about 25 % of *total thermal efficiency* at the draw hook, at low speeds, in spite of inferior mechan-

Fig. 31. — Diesel locomotive with pneumatic drive.

ical efficiency as compared with high class gear transmission. The heating of the air is also desirable when it is used for operating the normal locomotive cylinders, because it obviates the unduly low temperature, in consequence of expansion, as a result of the quick fall in the air temperature.

While the 1 200-H.P. Diesel motor represents the normal M. A. N. design, *the fast running compressor,* with its high delivery and its small clearances, which are necessary for good volumetric efficiency called for numerous test bed trials, and for similar reasons the air heater was only developed in its final form after trials on the test bed. Further experiments were required to determine if air could be used without fear of explosions in the compressor or the locomotive, caused by oil residues and the oxygen in the compressed air. It was because of these fears that exhaust gas was used in the small experimental Görlitz locomotive. It is of course desirable that clean air should be used for power if at all possible, in order to prevent the introduction of dirt with the air.

The very numerous experiments on the test bed, showed however, that the use of air was not to be thought of; safety valves were, in any case, fitted at selected points. All these trials make it apparent that the Diesel locomotive can only be brought to perfection after many years work.

The compressor, clearances in which call for very small play between piston top and cylinder head, and therefore high class work in shop, is fitted with mechanically operated inlet and automatic delivery valves which pass the compressed air, at a pressure of 7 at. (99.6 lb. per sq. inch) and a temperature of 200° C. (392° F.) into an air heater with a heating surface of 82.5 m² (888 sq. feet) the body of which is divided into a number of sections, lying at the side of the main Diesel motor. The pressure of 99.6 lb. was chosen so as to be able to use a single stage compressor. It supplies proportionately large locomotive cylinders which have a diameter of 710 mm. (28 inches) and can be worked with a cut off as low as 15 %. The piston valves of the locomotive itself are arranged for double admission and are operated by the customary Heusinger valve gear.

In addition to control by this gear the working of the locomotive can be regulated by the variation of the fuel supply to the Diesel motor. For specially careful driving a regulator is provided. The locomotive is shown in figure 31. She has already been subjected to tests on the roller testing machine at Esslingen and these have fulfilled expectations. The accurate tests on the rails will follow, by means of the dynamometer car, during which the comprehensive apparatus installed in it for thermal investigations will no doubt do good work in giving accurate analyses of the work done.

The leading dimensions of the Diesel air pressure locomotive are as follows :

	Continuous.	Short period.
Effective power output of engine	1 000	1 200 E. H. P.
Indicated power output of engine	1 350	1 630 I. H. P.
Revolutions per minute	400	450
Working air pressure	6.5 at. (92.4 lb. per sq. inch)	7 at. (99.6 lb. per sq. inch)

Temperature at locomotive cylinder	320° C. (608° F.) (approx.)	320° C. (608° F.) (approx.)
Tractive power at rail	11 200 kgr.	(24 691 lb.)
Diameter of Diesel cylinders	450 mm.	(17 11/16 inches)
Stroke of Diesel cylinders	420 —	(16 1/2 —)
Diameter of compressor cylinders	640 —	(25 1/4 —)
Piston stroke of compressor cylinders . . .	350 —	(13 3/4 —)
Diameter of locomotive cylinders	710 —	(28 —)
Piston stroke of locomotive cylinders	650 —	(25 5/8 —)
Driving wheels, diameter	1 600 —	(5 ft. 3 in.)
Maximum speed	80 km.	(50 miles) per hour.

[625 .258 & 656 .212.5]

REPORT No. 4

(Germany)

ON THE QUESTION OF THE METHODS TO BE USED IN MARSHALLING YARDS TO CONTROL THE SPEED OF VEHICLES BEING SHUNTED, AND TO ENSURE THEY TRAVEL ON TO THE LINES IN THE VARIOUS GROUPS OF SIDINGS (SUBJECT X FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION) (1),

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(German State Railway Company).

Figs. 1 to 65, pp. 312 to 366.

CONTENTS.

(1) Translated from the German.

PREFACE.

The German State Railway Company (Reichsbahn) has in addition to a number of small marshalling yards, 118 yards with a daily throughput of 2 000 wagons and more.

The existence of a great number of industrial centres in various parts of Germany has produced a close network of lines, the daily control of which requires an extraordinary amount of labour in shunting and which accounts for the large number of marshalling yards. No less than 25 % of the working costs of the entire goods traffic is due to the making up of goods trains. A great part of the average time taken from loading until next reloading is absorbed by making up the trains in the marshalling yards. Whether operation will remain easy, even at times of heavy pressure, or whether, owing to any unusual increase in traffic, difficulties and delays will occur, depends chiefly on the efficiency of the marshalling yards.

Owing to the importance of marshalling yards, the Reichsbahn attaches the greatest weight to their economical and efficient working.

In increasing measure the Company has begun to use special appliances of a technical nature to promote their development. Its endeavours to improve shunting operations by mechanisation have been applied chiefly to the main hump zone, that is to say, those lines through which all wagons arriving must pass. In this direction much pioneer work has been done by this Company.

It might therefore be of particular interest to become acquainted with the conditions existing on the Reichsbahn in this respect.

I. — General arrangements of shunting yards.

The various shunting yards work under very different conditions: their duties vary to a great extent, the output is varied, the constructional arrangements of the groups of lines in their relation one to another and their gradients are of great variety; there are old and new yards, the latter not infrequently altered and enlarged in accordance with the demands of increasing traffic.

For these reasons the various marshalling yards differ very much in appearance.

According to their gradients marshalling yards can be divided into yards with non-accelerating gradients, gravity yards and yards of mixed type.

Non-accelerating gradient yards are those where the gradients are such that wagons will not begin to move by themselves. The trains are pushed by locomotives over a hump whence the wagons reach the sorting sidings by means of their own gravity.

Gravity yards are those which are placed on such a gradient that wagons can be moved anywhere simply by the effect of gravity. The wagons run with the usual stops from one group of sidings to another.

Yards of mixed systems are those which have partly been constructed as non-accelerating yards and partly as gravity yards.

Of the 118 shunting yards of the Reichsbahn 113 are non-accelerating yards, 3 gravity yards (Dresden-Friedrichstadt, Nuremberg, and Chemnitz-Hilbersdorf) and 2 are yards of mixed system (Engelsdorf and Duisburg-Hochfeld-Süd) (see table).

TABLE.

Shunting yards with a throughput of 2 000 wagons per day and more.

Basic system.	Number of basic systems.		Daily throughput. 2 000-2 999 wagons.	3 000-3 999 wagons.	4 000 and more wagons.
Single non-accelerating yard	113	52	38	11	3
Double non-accelerating yard . . .		61	27	12	22
Gravity yard		3	...	1	2
Yard with mixed systems		2	1	1	...
Total. . .		118	66	25	27

Shunting yards, apart from a few exceptions, possess a common basic system consisting of the following parts : reception sidings, hump zone, direction sidings, station sidings, and departure sidings. In the case of single marshalling yards these groups of tracks occur once only. The double marshalling yards possess these groups in both main directions.

27 marshalling yards have a daily throughput of 4 000 wagons and more; of these 3 are single non-accelerating yards; 22 are double non-accelerating yards, and 2 are gravity yards. It will thus be seen that the greatest number of marshalling yards is of the double non-accelerating variety.

II. — Main hump zone.

As a rule, the tracks are arranged in such a way that the trains are sorted out on arrival. The reception sidings extend out from the arrival lines. In between the reception sidings and the sorting sidings is placed in every instance a *main hump zone*. The latter is the vital part of the entire shunting yard. All wagons arriving must pass through this in order to run directly to the sorting sidings. In doing so the gravity of the wagon is used as the motive power. It is true that at certain less important yards ordinary flat shunting is employed; but this however, is exceptional and need not be taken into consideration.

A. — Method of operation in non-accelerating yards.

In a considerable number of non-accelerating yards the reception sidings and sorting sidings are at approximately the same level; between them as part of the main lay-out, there is both an incline and decline (hump). This arrangement has, however, the disadvantage that the train must be pushed up to the full height necessary for running down (see fig. 1).

With other marshalling yards, the reception sidings are placed somewhat higher so that pushing over the hump is facilitated. (The height is reached by the kinetic energy of the arriving

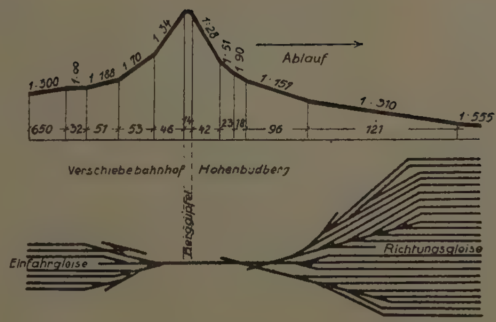

Fig. 1.
Reception sidings and shunting sidings at the same level.

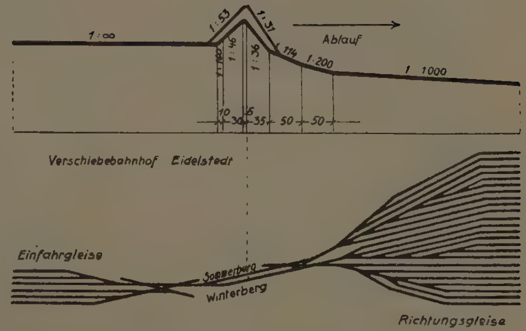

Fig. 2.
Reception sidings higher than shunting sidings.

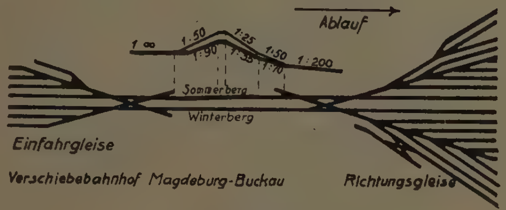

Fig. 3.
Reception sidings converging before reaching the hump.

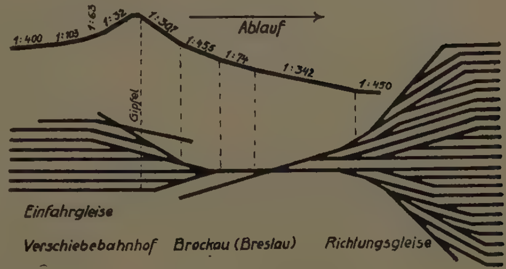

Fig. 4.
Reception sidings converging on the incline.

Explanation of German terms in figures 1 to 8: Ablauf = Incline. — Einfahrgleise = Reception sidings. — Berggipfel *or* Gipfel = Top of hump. — Richtungsgleise = Sorting sidings. — Sommerberg = Summer hump. — Verschiebebahnhof = Marshalling yard. — Winterberg = Winter hump.

train). As a rule there exists with this arrangement a small incline at the top. The object of this is to keep each wagon up against the buffers of the preceding one so that they can be more easily uncoupled (see fig. 2).

In most cases the arrival sidings converge before reaching the hump so that only one or two lines pass over it (see fig. 3). In a few others all or part of the arrival sidings are continued as far as the hump and they only converge on the incline (see fig. 4).

The trains, on arriving, are slowly pushed to the hump by means of a shunting locomotive. Just before reaching the top — the wagons are uncoupled singly or in groups — according to their destination. The detached wagons will then run down the incline by gravity. Their speed depends to an extent on the angle of the incline, and they will reach, in more or less close formation, their particular siding, where they are stopped by skids. In this operation spaces occur between the wagons so that they still have to be pushed together to enable them to be coupled. Subsequently the trains or groups of trains, if they do not immediately leave the sorting sidings, must be taken to special departure sidings where any final operations take place. Part of the groups of trains are previously sorted according to stations and subsidiary groups, this being generally done in a special station group.

B. — Method of operation in gravity yards.

In the case of gravity yards (which include yards of mixed systems, the reception sidings of which are arranged as in gravity yards) the reception sidings have rather a steep incline (generally 1 : 100). The beginning (the highest portion) of the reception sidings are somewhat flatter. The main hump zone is formed in continuation of the incline. As a rule the reception sidings are continued to the spot where the wagons are uncoupled and begin to descend by themselves. The lines converge on the incline only.

No locomotives are used for the shunting of the trains. The train runs under its own weight as far as the beginning of the hump whence the uncoupled wagons run singly or in groups into the destination sidings as in a non-accelerating yard. It will be shown later in detail how the shunting speed is regulated.

From the sorting sidings the wagons will run — with the usual stops — into their station order and thence into the departure sidings.

C. — Hump profile, height and arrangement of points in the hump zone.

The height and the profile of the hump in the main zone differ greatly at the various marshalling yards. The older hump zones are mostly lower and flatter than the new ones.

Owing to the great differences at normal and low temperatures in the running resistances of the wagons, many shunting yards are equipped with two humps side by side, but of different heights, *i. e.* with so-called summer and winter humps. (see fig. 5). The reception sidings are so arranged that the train can be pushed either over the summer hump or over the winter hump. The height of the summer hump is about 0.60 to 1 metre (2 ft. to 3 ft. 3 3/8 in.) less than that of the winter hump.

When using efficient rail brakes the winter hump alone would be sufficient (see fig. 6), since the greater speeds which result with favourable temperatures can easily be taken up by the brakes.

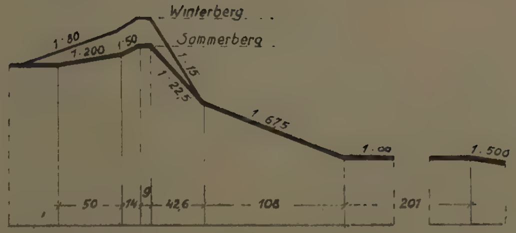

Fig. 5. — Two-hump marshalling yard (Bremen).

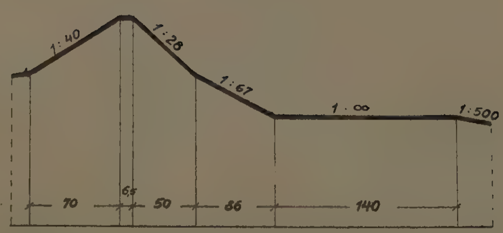

Fig. 6. — One-hump marshalling yard (Hamm).

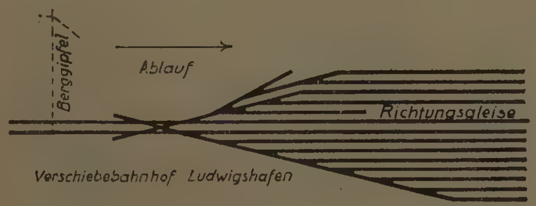

Fig. 7. — Sorting sidings of the « ladder » system.

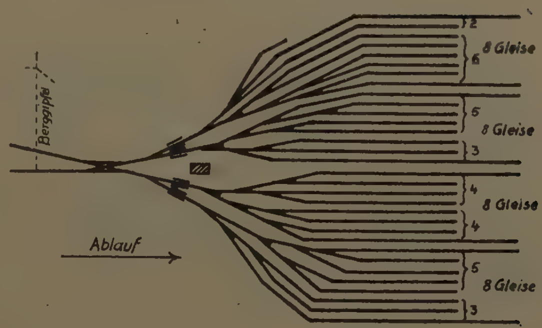

Fig. 8. — Sorting sidings of the « balloon » system.

In all the older layouts the incline is made up of a succession of gradients, commencing with 1 : 25 to 1 : 40, then 1 : 50 to 1 : 100; further 1 : 100 to 1 : 200, and finally 1 : 300 to 1 : 600 or even flatter, until it reaches the sorting sidings.

The points are mostly used on main routes (see fig. 7) and are frequently at a great distance from the hump.

The modern hump zones begin with a steep incline of 1 : 15 — 1 : 25, thence to a gradient of 1 : 60 — 1 : 80 and ending on the level or on a very slight incline.

Much importance is attached to arranging the points within as close a radius as possible (see fig. 8), the tracks being bunched together in such a manner that at each point there branches off, if possible, an equal number of tracks.

It will be shown at a later stage why the development has taken this course. The efficiency of the hump zone is decisively influenced both by the height and profile of the hump and the arrangement of the points. For this reason all new layouts have been designed in accordance with *dynamic theory.*

D. — Hump yard dynamics.

Difficulties arise owing to the difference in the running resistance of the wagons and groups of wagons. According to the law of dynamics descending wagons follow each other at equal speeds and at equal distances provided they are submitted to the same running resistance. The running resistances, however, vary even at normal temperature between approximately 2.8 ‰ and 4.5 ‰ and at low temperatures between 5.6 ‰ and 9 ‰. To this will have to be added the resistances due to curves and the air resistance which frequently increases still further the difference in the running resistance.

Figure 9 will show the basic resistance for various wagons and groups of wagons at normal and low temperatures.

	Normal temperatures.	Low temperatures.
	Basic resistance, in kgr./tonne (lb./Engl. ton).	Basic resistance, in kgr./tonne (lb./Engl. ton).
Bad runner (1 empty covered wagon). . . .	4.5 (10.0)	9.0 (20.0)
Good runner (1 loaded open top wagon) . .	2.8 (6.3)	5.6 (12.6)
2 empty covered wagons .	4.2 (9.4)	8.4 (18.8)
2 loaded open top wagons.	2.5 (5.6)	5.0 (11.2)
3 empty covered wagons .	4 0 (9.0)	8.0 (18.0)
3 loaded open top wagons.	2.4 (5.4)	4.8 (10.8)
5 empty covered wagons .	3 9 (8.7)	7.8 (17.4)
5 loaded open top wagons.	2.2 (4.9)	4.4 (9.8)

Fig. 9. — Values of basic resistances.

Figures 10 and 11 clearly illustrate the amount of track and curve resistance expressed in resistance height.

Figure 12 will show to what extent the air resistance depends on the relative speeds of the wagons.

Owing to the different running resistances the wagons acquire different running speeds and distances. In order to traverse the danger zone (*i. e.* the distance from the hump to the last point) each truck requires a different running time, a feature which is the cause of much trouble in shunting operations.

1) *Requisite height of hump.*

The distance which a wagon runs depends on the height of the hump and the running resistance.

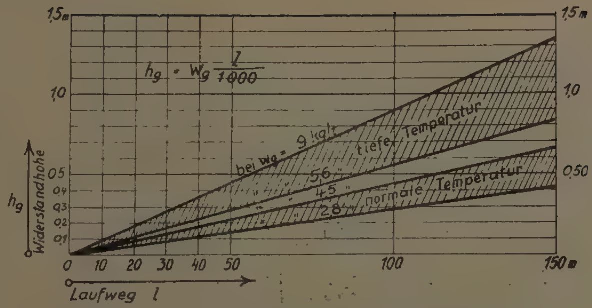

Fig. 10. — Track resistance expressed in resistance height.

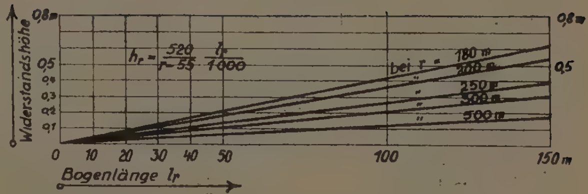

Fig. 11. — Curve resistance expressed in resistance height.

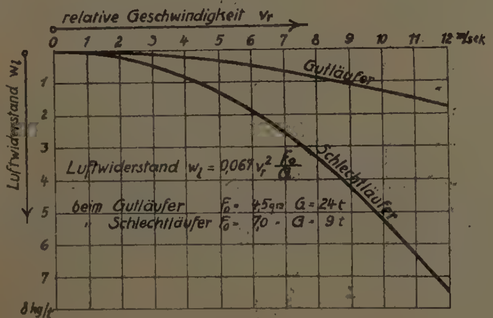

Fig. 12. — Values of air resistances.

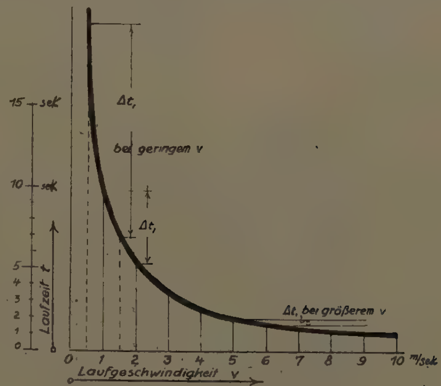

Fig. 13. — Running time differences decrease as running speed increases.

Legend: $t = \frac{l}{v}$ (here $l = 10$ *metres*;

Δ'_1 = **Running time difference between shunting speeds increasing by 1 meter per second.**

Explanation of German terms in figures 10 to 13: Bei geringem (grosserem) V = At low (higher) speed. — Bogenlänge = Lengths of curves. — Gutläufer = Good runners. — Laufweg = Distance run. — Laufzeit = Running time. — Luftwiderstand = Air resistance. — Normale Temperatur = Normal temperature. — Relative Geschwindigkeit = Relative speed. — Schlechtläufer = Bad runners. — Tiefe Temperatur = Low temperature. — Widerstandshöhe = Resistance height.

It is almost completely independent of the speed at which a wagon travels or of the time it runs. In short, the running distance is almost independent of the design of the gradient.

The distance which a wagon runs varies within very wide limits on account of the running resistance. The differences are particularly great at high and low temperatures (beginning at about — 4° C [24.8° F]) and also where the wind is with or against the wagon.

How high should the hump be built?

To-day the general rule is to choose the height of the hump so that the bad runners in unfavourable weather will run at least 100 m. (328 feet) into the sorting sidings. By unfavourable weather is generally meant : *low temperature and absence of wind*, and in special cases when the yard is frequently exposed to head winds : *low temperature with head winds.*

In the event of two different humps being provided, the summer hump may be of smaller dimensions.

When deciding between *one* hump or *two* different humps for the reception sidings, one must, however, take into consideration that continuous working can only be accomplished if care is taken that the time between the running down of the last wagon of one train and that of the first wagon of the following train is practically nil. This can only be done if at least two humps of *equal* height which can be used alternately are available. Whilst one train is being shunted the next can advance towards the top, so as to begin shunting as soon as the last wagon of the previous train has started.

In calculating the height of the hump, one generally leaves out of account the gradient of the sorting sidings.

The theoretical calculation of the necessary height generally results in a high hump, which in the majority of runners gives too great a speed. One is thus forced to install efficient rail brakes which will have no difficulty in braking any excessive speeds.

2) *Maximum speed of shunting at reception sidings.*

The efficiency of the hump zone is made all the greater by the rate at which the trains are shunted.

This speed, however, must not be so great that the various wagons will foul each other in the danger zone or that there will not be sufficient time to throw the points between them.

The *theoretical shunting time* — expressed by the difference in time between each wagon at its centre of gravity, at the point of descent — is determined by the following equation :

$$t_o = \Delta t + t_s,$$

wherein Δt is the running time difference between a bad runner and a good runner and t_s is the time during which the points are occupied *i. e.* the shortest interval in which one wagon may be followed by another.

If one expresses the classification work in terms of shunting speeds v_0 one arrives at the relation $v_0 = \frac{L_w}{t_o}$ in which L_w is the length of the wagon.

From this equation it can be seen that a large number of cuts can only be dealt with by reducing the running time differences as well as point occupation time to the smallest figure.

3) *Reduction of the running time differences.*

The necessity for keeping the running time differences as low as possible is looked after in all new installations by

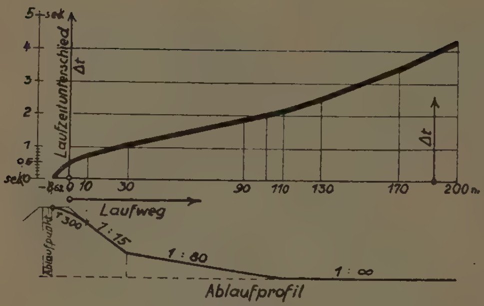

Fig. 14. — Running time differences increase with the distance run.

Explanation of German terms: Ablaufprofil = Profile of incline. — Ablaufpunkt = Top of incline. — Laufzeitunterschied = Running time differences.

the selection of a suitable profile, a suitable distribution of the points and efficient rail brakes.

According to the laws of dynamics the running time differences become smaller as the speeds increase (see fig. 13). In order to give the necessary speed to the wagons as quickly as possible *the hump begins with a steep gradient* (1 : 15 — 1 : 25) and the running resistance is then of not much importance. The wagons can therefore follow each other in closer succession because they run more uniformly.

The steep portion of the gradient should be extended at least so far as to give the wagons a maximum speed of 5 metres (16 ft. 5 in.) a second.

In order that they may reach the steep gradient as quickly as possible, the radius of the hump is made as small as possible. So that locomotives can pass over the hump, its radius is usually not less than 300 m. (984 feet).

The hump gradient should be followed by an intermediate gradient (1 : 60 — 1 : 80) before it finally passes into the level portion or to a very slight decline. In this manner a useful profile is obtained over which the running time of the wagon is small wthout the speed being excessive. It is not theoretically the best profile, but this would require a gradient which, from the point of view of the safety of the traffic would appear to be undesirable.

Another law of dynamics shows that the running time differences increase with the distance from the starting point (see fig. 14). It follows therefrom that one should aim at a very small *danger zone.*

Therefore, with new installations the first point is brought close to the hump; the points are kept close together and the tracks are bunched together (see figs. 15 *a*, *b* and 16).

The layout should be made as symetrical as possible in such a manner that from each point an equal number of lines branch out. By so doing one obtains the advantage of keeping the points within a small radius : the majority of the trucks will pass over those points nearest the hump so that most wagons will only have a short travelling distance together with small differences in their running times. This advantage could still be increased by the efficient use of the sorting sidings in such a manner that only a small proportion of the cuts would pass over the furthest points.

The arrangement of the points, however, is affected by the installation of rail brakes. On principle one ought to connect as few tracks as possible to one brake, but as efficient rail brakes are still comparatively expensive there must be some limit to this procedure. There should not, however, be too great a distance between the points and the brakes.

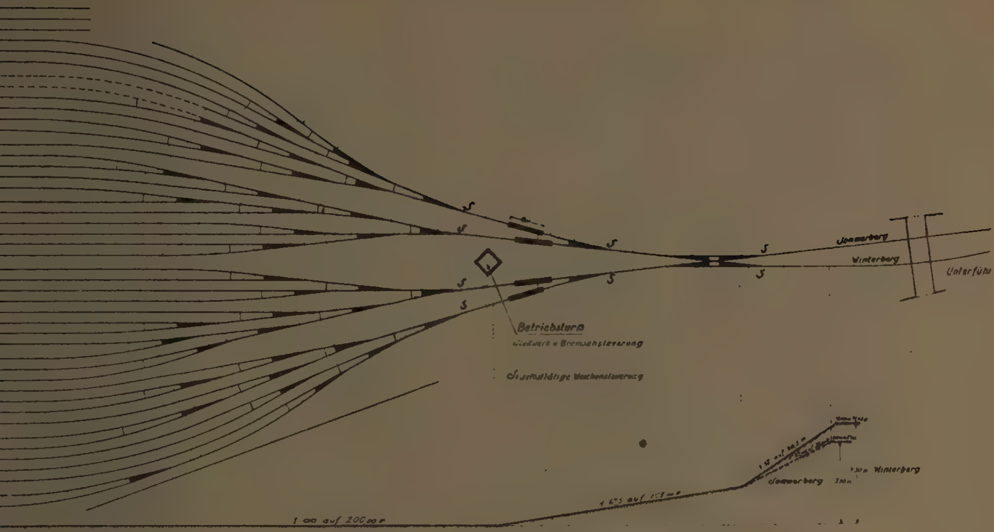

Fig. 15*a*. — « Balloon » type sorting sidings of the marshalling yard at Bremen.

Explanation of German terms: Betriebsturm. Stellwerk u. Bremsensteuerung = Control tower. Switching apparatus and brake
l. — Selbsttätige Weichensteuerung = Automatic points. — Sommerberg = Summer hump. — Winterberg = Winter hump.

Fig. 15*b*. — View (taken from control tower) of left half of the sorting sidings at Bremen.

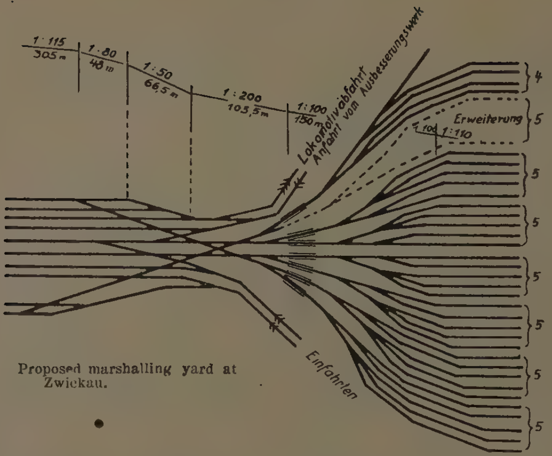

Fig. 16. — « Balloon » type sorting sidings in a gravity yard.

Explanation of German terms: Anfahrt vom Ausbesserungswerk = Arrival from repair shops. — Einfahrten = Arrival lines. — Lokomotivabfahrt = Locomotive departure line.

It should also be mentioned that standard turn-outs are still normally used. Close study of the question has revealed that although certain advantages are obtained by the use of sharper angled points, not much length is gained for shortening the danger zone.

4) *Reduction of the time during which the points are occupied.*

In a previous paragraph it has been shown that in order to obtain a large throughput the time during which the points are occupied should be as small as possible.

This period is affected by the method of working and design of the point operating gear.

If the points are worked by a pointsman the following details are of importance :

1. *The period of occupation* t_z, *i. e.* the time during which the front axle passes over the tongue of the point, and the trailing axle leaves it.

2. *The throwing time* t_w, *i. e.* the time which is necessary for throwing the point, commencing with the throwing motion of the operating device and ending with the final position of the tongue of the point.

The blocking time t_s then is :

$$t_s = t_z + t_w.$$

The throwing time t_w is very small when the point is actuated by a device erected close to the point. It will then amount to only 0.5 to 0.7 second. This, however, requires a large staff and therefore as a rule point frames have been constructed which generally actuate all the points, or at least a considerable number of them. The mechanical locking frames which are worked by rodding are somewhat better than those worked by

wire. In the former case the throwing time is 1.5 to 2.5 seconds and in the letter 2 to 3 seconds. With power locking frames the throwing time is chiefly dependent on the speed of the point gear. Mostly it is about 2.5 seconds.

In view of the enormous bearing which a high speed point operating gear has on the time during which the points are occupied, when power locking frames are in use, efforts have been made to produce point operating gears of extraordinary speed and success has been attained by reducing the throwing time to 0.5 to 0.4 second which has meant a very great improvement in the shunting speed. At a number of the newly erected or rebuilt frames similar point operating gear has been used with good results.

The theoretical time for point occupation resulting from the above mentioned throwing time cannot be obtained in practice; it will be greater because the pointsman requires a certain time for reading the cut card and is unable to judge accurately the right moment for throwing the points — especially when they are distant, and he is bound to work on the safe side.

It meant, therefore, a further important step towards perfection when *automatic frames* were designed by which the throwing of the points by the wagon itself was made possible. By this means the foremost points through which the majority of the wagons passed could be made automatic, the time of point occupation being, therefore, reduced to a minimum.

When the points are controlled by the wagon itself the point is locked by an insulated rail of a length i (insulated length) which length, measured from the last axle of the preceding vehicle to the first axle of the following, must remain clear to enable the point to be thrown between the two vehicles. The insulated length begins at such a distance from the point of the tongue that a wagon requires as much time to travel from there to the point of the tongue as the throwing time of the switch; it finishes at the point tongue. The greatest locking time therefore amounts to :

$$t_s = \frac{i + a}{v_{min}}$$

wherein a indicates the wheel-base and v_{min} the slowest wagon speed in the insulated length i.

With these formulas one is in a position to determine exactly whether an automatic installation will be successful and thus can decide in advance whether it will work economically.

5) *Operation of rail brakes.*

The running time differences of the wagons can be still further diminished by using rail brakes which enable one to increase the running time of a good runner so that it approximates that of a bad runner. The method of braking which merely serves this purpose may be called for short *interval braking*.

In the older yards skid brakes are used; in some yards, more particularly the modern ones, rail brakes with distant control are in use (a more detailed description of the various kinds of rail brakes will be found below).

The rail brakes are generally so arranged that each wagon during its travel through the danger zone passes through only one brake.

It is a moot point where and how many brakes should be installed.

If the brakes are placed a short distance below the hump (hump brake) it is theoretically possible to do away with

the running time differences by light braking, because even a small amount of braking within the low speed area produces considerable retardation. A factor of difficulty in « interval braking » in this position is that the brakesman is not able to judge with certainty the running capacity of each wagon.

However, by placing the rail brake at the foot of the hump or in the middle of the point zone (« valley brake ») the running time differences can also be done away with theoretically and the brakesman can observe the wagon during its travel towards the brake and thus estimate its running capacity. It is, however, necessary that at this position a more or less large portion of the momentum of the wagon should be absorbed by the brakes in order to produce a sufficient reduction in speed and thereby an effective retardation of the good runners, as the speed is only reduced in proportion to the square root of the kinetic energy.

There is also a further point to be remembered if one wishes to determine the best position for the rail brakes. On the higher gradients the heavy good runners attain such a momentum that very often they can only be stopped with great difficulty in the sorting sidings. Therefore it is useful and even necessary to brake these wagons beforehand so that they may be stopped more easily. The braking which has this only for its object may be called for short *advance braking*. For this purpose the « valley brakes » are very suitable, because a heavy wagon can be deprived of a considerable portion of its momentum within the high speed area without the running time being influenced in the same degree because the kinetic energy is reduced in proportion to the square of the speed.

Furthermore, with high humps and steep gradients and points within a small area, the importance of *interval braking* is not so great, as dangerous running time differences will only occasionally occur.

One is thus forced to the conclusion that the *valley brakes* should be preferred to hump brakes in order to carry out, firstly *advance braking* and secondly, — if still necessary — *interval braking*.

If the advance braking can be done so effectively as to make subsequent braking in the sorting sidings unnecessary *i. e.* if the brakesman brakes the wagon in the valley brake so much that it comes to a stop at the desired spot, this would be *distance braking*, therefore, the brakesman will always have to estimate the braking effort necessary according to the distance the wagon has to run and the running qualities of the wagon. This, of course, makes good powers of observation and judgment necessary.

It is evident that the perfect braking of each wagon will then only be successful if the brakesman does not have to take into consideration either the preceding or the following wagon. The best position for such brakes would therefore be behind the point zone, but for this there would be required as many rail brakes as there exist sidings. The installation would thus become very expensive. If it is desired to work with fewer rail brakes, a midway solution will have to be decided upon which will furthermore allow *interval braking* as well as *distance braking*. In principle *distance braking* is easier the nearer the rail brakes are to the last points.

How far can one count on the possibility of *distance braking* with brakes situated within the point zone? In the first place all cuts which diverge before reaching the brakes can be braked accur-

ately without difficulty. With a good point lay-out and even when using a few rail brakes, these may form a high percentage. Further, one can count on all wagons with approximately the same distances to run from the hump or with equally short distances to travel in adjoining routes (*i. e.* cuts parting at the first point after braking) being accurately braked without much difficulty because anyhow the speed of shunting cannot be so much increased that there remains no margin.

There remain therefore only a few unfavourable cases (for instance good runners with a short way to run followed by bad runners having to run far, also diverging of the cuts at one of the last points) where distance braking will interfere with interval braking. In such cases the skid operators, who are working in the sorting sidings and who are warned by the cut cards or by hooter signals, will see to the final braking.

It should nevertheless be kept in mind that the gradient must be suitable for distance braking and that the point zone behind the rail brakes must be level because in each case the wagons which have been braked for the correct distance will traverse this part of the danger zone more uniformly. Even a wagon which may have been braked for a near destination must leave the brake with a comparatively high speed in order to reach the same because on the level it loses more in kinetic energy than on the incline. The following wagon can therefore not so easily catch up.

Therefore there is no doubt that one may be assured that provided the layout is properly schemed, accurate distance braking is possible and that it will result in economies in skid operators and in closing-up work in the sorting sidings

The existing installations at Hamm, Bremen and Duisburg-Hochfeld-Süd confirm the foregoing remarks

Thought has also been given to the removing of the existing differences in running factors by a method which would be the counterpart to the rail brakes, *i. e.* by means of an « accelerator apparatus » by which the running qualities of the bad runners are brought up to those of the good runners. Instead of making the humps very high and braking the excess energy the humps could be kept lower and any further effort could be supplied by an acceleration plant. The Deutsche Reichsbahn has made this experiment by installing at the marshalling yard in Osnabrück an accelerator designed by the *Gesellschaft für Oberbauforschung* (a full description will be found below).

E. — Protection against wind.

The efficiency of the shunting yard is often diminished by strong winds. More particularly is it so with the older installations with the *ladder* layout of points and a low height of hump, which suffer from contrary winds. An effective counter measure is offered by the erection of wind protection structures of which the Reichsbahn is already making use to a considerable extent (see fig. 17).

We distinguish between the two kinds of wind protection namely : natural and artificial.

In order to obtain *natural protection* from winds, poplars are used almost exclusively; they stand at a distance of about 1.25 m. (4 feet) from one another when planted in a single row and about 2 m. (6 ft. 6 3/4 in.) in a double row.

It takes from 8 to 10 years before the plantation becomes effective. The pop-

Division.	Marshalling yards.	Kind of protection.		
		Length. Metres (feet).	Width. Metres (feet).	Plantations. P = Poplars. S = Spruce.
Altona	Eidelstedt	...	...	600 P
	Flensburg-Weiche	. .	. .	200 P and S
Berlin	Wustermark	...	...	200 P
Breslau . . .	Schlauroth.	47 00 (154)	...	200 P
Elberfeld . . .	Geisecke	...	...	900 P
	Holzwicked	...	. .	300 P
Erfurt	Gotha	...	...	300 P
Frankfurt (Main)	Bebra	277.00 (909)	...	...
	Fulda	40.65 (133)	...	...
	Giessen.	127.50 (418)	27 50 (90)	. .
Halle	Falkenberg HSG.	...	14.87 (49)	...
	Leipzig-Wahren	520.00 (1 706)	23.70 (78)	...
Karlsruhe. . .	Mannheim.	540.50 (1 773)	...	.
	Karlsruhe	200.00 (656)	...	. .
Magdeburg . .	Halberstadt	275.00 (902)	30.56 (100)	332 P
	Oschersleben (Bode).	...	...	400 P
	Magdeburg-Rothensee	470.00 (1 542)	. .	672 P
	Magdeburg-Buckau	536.00 (1 759)	...	880 P
Mainz	Mannheim-Waldhof.	...	...	420 P
	Oberlahnstein.	...	...	432 P
Münster . . .	Osnabrück.	...	. .	600 P
	Papenburg.	...	...	160 P
	Rheine	. .	...	90 P
Oldenburg. . .	Oldenburg	150 00 (492)	...	750 P
Osten	Frankfurt (Oder).	...	...	320 P
	Neu Bentschen	...	...	300 P
Stettin. . . .	Pasewalk	55.00 (180)	...	. .
	Stralsund	270.00 (886)	...	...
	Templin	...	...	120 P

Fig. 17. — List of existing wind protection installations.

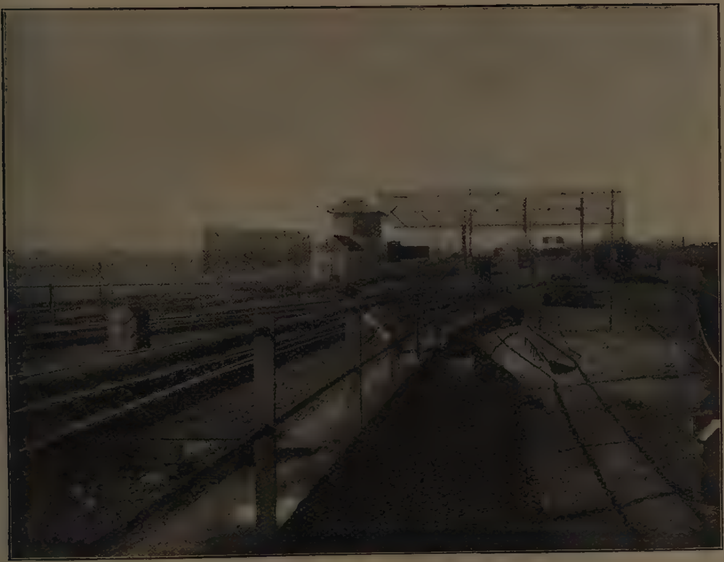

Fig. 18. — Wind protection installations in marshalling yard at Giessen.

lars will then have reached a height of about 15 m. and they are consequently suitable for giving protection at fair distances, *i. e.* to entire groups of tracks.

Artificial protection against wind is obtained from lattice screens which break up the wind but do not affect visibility (thus keeping the visibility of the yard good).

A good efficiency in protection is obtained when the laths and interstices between them are of equal width (reduction of wind speed by about 40 to 60 % and of pressure by 60 to 80 %). The laths should measure about 5 to 8 cm. (2 to 3 1/8 inches) in width and about 3-5 cm. (1 3/16 to 2 inches) in thickness.

The screens are generally constructed longitudinally but they may be made crosswise if necessary (see fig. 18).

These screens are mostly placed at right angles to the direction of the most unfavourable wind and if possible close to the track. Care should, however, be taken that no surfaces be offered to winds in either direction which would have the effect of guiding the wind against the direction of shunting. For this reason the wind screens are mostly placed staggered. The view of the control tower and the shunting staff must not be obstructed (see plan according to fig. 19).

III. — Auxiliary means for regulating the humping speed.

A. — Yards with non-accelerating gradients.

In yards with non-accelerating gradients the trains to be shunted are pushed

over the hump by *steam locomotives*. We have seen that the maximum humping speed is the measure of the efficiency of a shunting yard. Under working conditions, however, it is not easy to operate *at the maximum speed*, and thereby fully to take advantage of the possible efficiency.

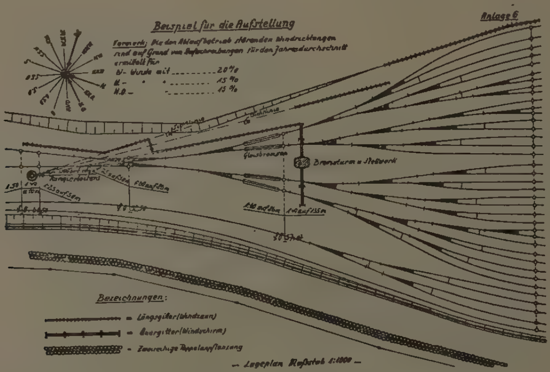

Fig. 19. — Diagram of wind protection installation.

Explanation of German terms: Top: Beispiel für die Aufstellung. — Vermerk, etc. = Example of installation: Wind directions impeding shunting by gravity are given for the different seasons of the year the following average values: Easterly winds... 20 %; Northerly winds... 15 %; North-easterly... 15 %. — *In the sketch:* Standort des Rangierleiters = Head shunter's post. — Bremsturm und Stellwerk = Control tower (points and brakes). — Lichtlinie = Limit of sight. — Gleisbremsen = Rail brakes. — Bottom: Langegitter (Windzaun) = Longitudinal wind screen. — Quergitter (Windschirm). — Cross wind screen. — Zweireihige Pappelnanpflanzung = Double row of poplars. — Lageplan Masstab.. = Scale 1/1000.

a) Stop. *b*) Push slowly. *c*) Push at moderate speed.

Fig. 20. — Three-aspect hump signal.

Let us now examine the devices which are available to the head shunter for regulating the humping speed and in which direction efforts are being made to obtain perfect regulation.

Generally the marshalling yards are equipped with an optical signal (signal No. 40 of the Signalling Regulations) which is able to indicate three signals: « Stop », « Shunt slowly » and « Shunt at moderate speed » (see figs. 20 and 21). This signal gives the same indication by

Fig. 21. — Hump signal (arm type).

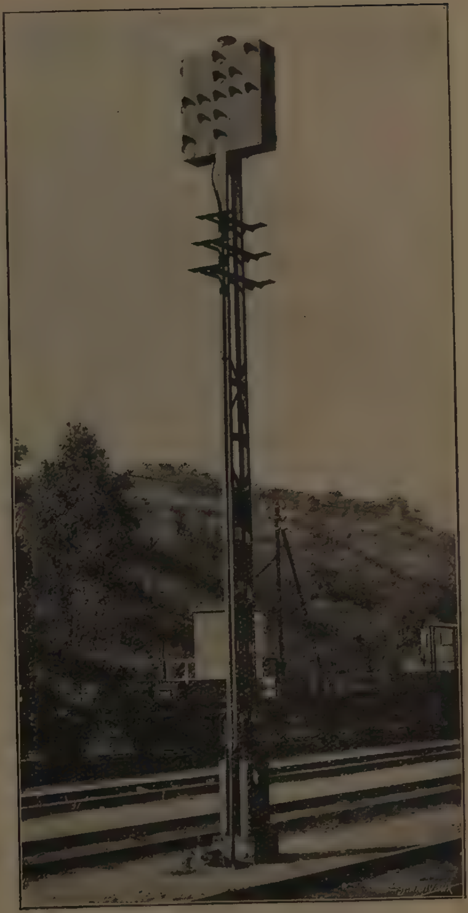

Fig. 22. — Hump signal (daylight type).

day as by night. In front of a black disc there rotates a white arm which is curved parabolically so that it can be illuminated at night time by means of a lamp. The three signals are given by moving the arm to a horizontal, slanting or vertical position. This signal is generally at the top of the hump near the head shunter's hut. For safety this signal is often provided with an electrically actuated « stop » device which can also be operated from the control tower.

In order to be able to transmit messages equally well during mist or fog, acoustic signals are used as well the shunting signal. Along the reception sidings, uprights at fairly long intervals [80-100 m. (262 to 328 feet)], are erected which carry bells, or, which is more effective still, hooters. It is useful to mention here the « tyfone » of the Germania Shipyard (Kiel) which consists of a diaphragm loud speaker worked by air pressure. The optical shunting signal is frequently connected with the acoustic signals making the latter sound at each change.

In order to be able easily to erect and operate signals which indicate the same as the main shunting signal, alongside the reception sidings, the method of making the shunting signal a daylight signal has been recently successfully adopted (see fig. 22). Horizontal, slanting and vertical « strips » of light are formed by separate lamps, and the electrical operation of the signal is exceedingly simple.

The optical and acoustic signals have generally proved their worth; however, for frequent and accurate regulation of the shunting speed they are not sufficient. In order to make regular shunting possible it is not only necessary to adjust the speed to the temperatures and winds prevailing at the time, but also to do it during humping, owing to the presence of good and bad runners, whether the cuts run singly or in groups, and whether the cuts have long or short distances to travel. The running time differences depend on all these factors which for their part determine the possible maximum of the shunting speed.

For this reason efforts have been made for some time to construct economically-sound devices which will communicate the orders direct to the humping engines; two types of wireless installations have been successful; the *Lorenz* system and the *Telefunken* system.

With the *Lorenz* type (makers: C. Lorenz A.-G., Berlin-Tempelhof) the orders are communicated by hooter or bell to the driver's cab of the humping locomotive. The head shunter by pressing a key closes a circuit which is formed by a wire and earth. The wire is insulated and is carried on poles alongside the reception sidings and the current is supplied by a dynamo generating alternating current. By this means electro-magnetic fields are formed which emanate from the wire. The fields excite a small frame aerial on the locomotive (see fig 23*a*). This is connected to an amplifier similar to the radio apparatus (see fig. 23*b*) which produces sounds in a loud speaker (hooter). This offers the possibility, by using a number of Morse signals, of obtaining exactly defined speeds for shunting so that the personal judgment of the engine driver comes but little into question. The Lorenz system is working in the yards at Erfurt, Halle, Saalfeld, and Hamm. To enable the engine driver to keep strictly to the desired speed, it is expedient to equip the humping engine with a speedometer which will accurately indicate the low speeds which obtain during humping. At the marshalling yard in Hamm Deuta speedometers are successfully used.

With the *Telefunken* type (Telefunken Gesellschaft für drahtlose Telegraphie, Berlin S. W. 11.) the transmission of orders takes place by means of wireless telephony (see figs 24 and 25). The first trial installation was made at the Berlin-Pankow marshalling yard. From his usual position, the head shunter passes his orders telephonically to the humping engine which is equipped with a receiver and loud speaker. A wire serves as the reception aerial and is strung between the chimney and the cab. A Telefunken

Fig. 23*a*. — « Lorenz » wireless installation. Engine with frame antennæ.

installation is used with very good success at the marshalling yard in Duisburg-Hochfeld-Süd for giving orders from one point to all the shunting engines in the yard.

Wireless installations have the advantage that orders can be broadcast anywhere and can be carried on quite independently of the weather and light conditions. Nevertheless there remain varying time intervals between order and execution caused by the degree of receptivity of the engine drivers themselves and the impossibility of determining and executing alterations in speed within small limits. It would therefore be best if the head shunter were personally and directly to control the humping so as to get the fullest efficiency out of the yard. As early as 1925 the Railway Company's district administration at Munich intended, on the occasion of the Munich Travel Exhibition, to make trials with a distantly controlled Diesel locomotive, but the idea has not materialised There has lately been some talk about experimenting with a *distance controlled electric locomotive.*

The distant control is only to take effect during the shunting proper by means of the well known *Leonhard* circuit. The reception sidings are equipped with an overhead line which supplies current to the locomotive during shunting. In order to enable the electric locomotive to run over such tracks as have no overhead line, it is to be provided with accumulators which will be continuously charged by means of a Diesel motor. The locomotive is to be manned by one person only.

From this electric locomotive not only does one expect advantages in working by accelerating shunting by means of an accurate regulation of the shunting speed, but also economic advantages as regards the annual working and maintenance costs.

Fig. 23b. — « Lorenz » wireless installation. Amplifier with hooter.

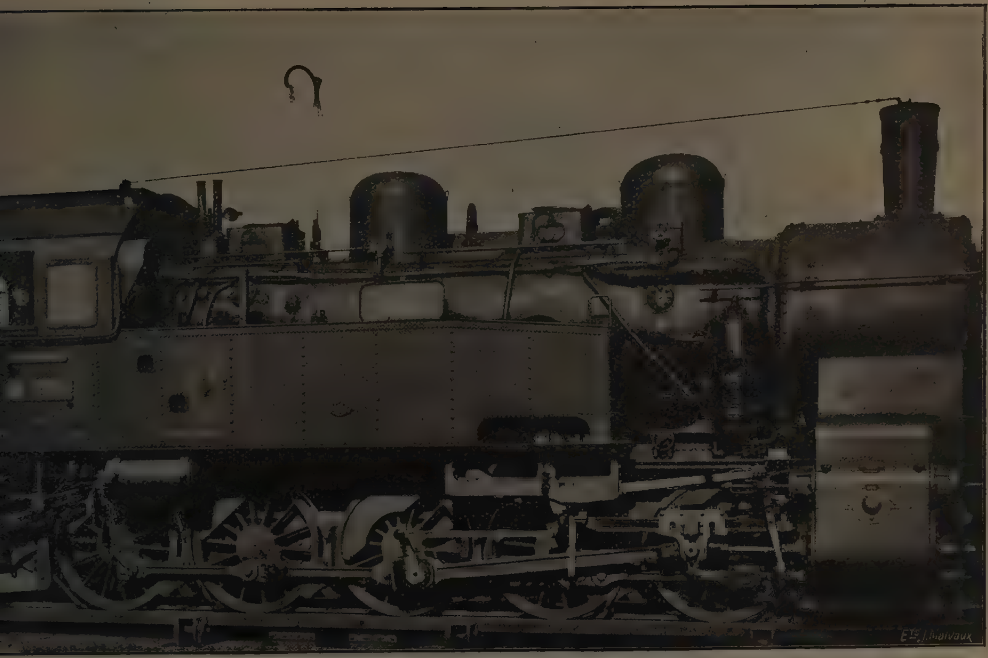

Fig. 24. — « Telefunken » wireless installation. Locomotive with antennæ.

B. — **Gravity yards :**

In gravity yards (and yards with mixed systems of gravity sidings) no shunting locomotives are used, the trains to be shunted owing to the gradient of the reception sidings, roll down automatically, and are brought to the commencement of the incline whence the uncoupled trucks run singly or in groups into the sorting sidings as in non-accelerating yards.

The train generally is manned by a few brakesmen who carry out the braking operations in accordance with the signals from the head shunter. However, by this method the speed of the train can only be varied very slowly because the brakesmen do not receive the signals quickly enough, and the braking effect is also variable. The wireless installations which have been successfully tried for the transmission of orders in non-accelerating yards are unfortunately not suitable for gravity yards on account of the brakesmen being in various parts of the yard.

The Reichsbahn has therefore proceeded to construct shunting apparatus which would remove this disadvantage. These are the *rope shunting yards* and the *gravity rail brake installation*. The chief point of these devices consists in the control of the humping speed being placed

in the hands of one man only, the head shunter, who is posted at the point where the humping begins and who can watch the working of the train and also the progress of the wagons. By doing this, the humping speed can be varied quickly and safely and can be well adapted to prevailing conditions.

Fig. 25. — « Telefunken » wireless installation. Locomotive receiver with battery.

The first *distant controlled rope shunting* yard was started in 1928 in the marshalling yard at Dresden-Friedrichstadt. It was constructed by the firms of Ernst Heckel, Gesellschaft für Förderanlagen, Saarbrücken, as regards the rope installations and the Gesellschaft für Oberbauforschung, Berlin, as regards the electrical portion.

The basic idea of the installation is the following : The descending train is attached to a *rope truck* by means of a « hook » and is started by the slackening of the rope truck which is clear of the loading gauge, moves on a special narrow gauge track between the rails and is prevented from lifting by weights and a special guide : it is attached to an endless rope which is run between the rails. The rope is taken over a stationary engine so that thereby considerable braking effort is applied to the train to be shunted, or if necessary even a slight pressure (acceleration) can be effected (see figs. 26 *a*/*b*).

Before the descent of the last wagon, the hook is uncoupled (see fig. 27 *a*). It then rests free of the loading gauge on a small « hook » truck which is joined to the rope truck (see fig. 27 *b*); the rope truck can therefore be safely brought back under the next train to be shunted. In order to save costs separate endless

Fig. 26*a*. — Rope shunting yard at Dresden-Friedrichstadt.
Rope truck.

Fig. 26*b*. — Coupling the rope truck.

Fig. 27*a*. — Uncoupling the rope truck.

Fig. 27*b*. — Hook in « off » position.

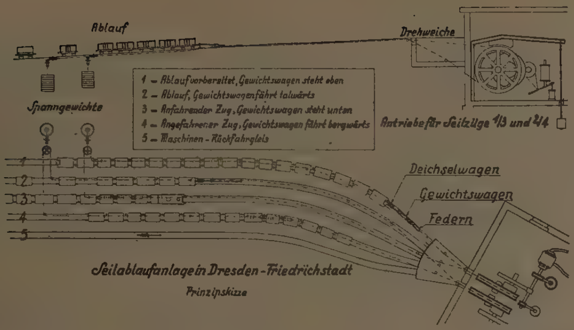

Fig. 28. — Rope shunting installation at Dresden-Friedrichstadt. Theoretical sketch.

Explanation of German terms: Ablauf = Incline. — Antriebe für Seilzüge 1/3 und 2/4 = Driving gear for cuts 1/3 and 2/4. — Dechselwagen = Hook-truck. — Drehweiche = Change-over point. — Federn = Springs. — Gewichtswagen = Truck carrying weights. — Spanngewichte = Tension loads.

1 = Prepared for descent, weight-carrying truck in uppermost position.
2 = Descent, weight-carrying truck runs downhill.
3 = Ascending cut, weight-carrying truck down.
4 = Cut well on gradient, weight-carrying truck runs uphill.
5 = Machines — Return track.

Fig. 29. — Control cabin of rope shunting yard, Dresden-Friedrichstadt.

ropes have not been provided for each track, but two tracks are coupled together (track 1 with 3 and track 2 with 4) (see fig. 28). When the rope truck allows a train to descend and travels downhill, the rope truck in the corresponding track will travel uphill. Whilst one train descends the next one on the neighbouring track can be prepared, and brought to the point of descent, thus making continuous operation possible. The operator's stand is in an overhead signal cabin (see fig. 29) above the sidings, which provides an excellent view. The head shunter faces the reception sidings and he can see the sorting sidings in a mirror. Control is effected by the Leonhard circuit which gives the advantage that the speed can be controlled independently of whether it is necessary to brake or to push.

The apparatus works faultlessly; it has not failed even under unfavourable weather conditions.

At present a second rope plant is being erected at Chemnitz-Hilbersdorf and as the reception sidings are placed in a unfavourable incline, it is frequently necessary to provide considerable pressure during shunting. The coupling device is so designed that the pressure acts on the buffers. If is to be expected that this installation will give a considerable increase in the throughput for Chemnitz-Hilbersdorf.

A *yard with brakes near the top* of the hump was arranged in Duisburg-Hochfeld-Süd in 1928. One brake lies at a short distance before the steep gradient in each of the three tracks (see figs. 30 and 31). The regulation of the humping speed of the train to be shunted is effected by braking the front part of the train by means of these rail brakes which are distantly controlled by the head shunter. The braking effort can be increased to such an extent that the train can be brought to a complete standstill.

The operation is as follows :

A train entering the reception sidings stops a short distance before entering the brakes whereupon the hand brakes of the first few wagons are put on and the vacuum brake is released; the locomotive then moves off.

The train remains in position whilst all preparations for the shunting are made (uncoupling the vacuum brake pipes, filling in the cut cards, etc.) thereupon the train is allowed to enter the brakes slowly by slackening the hand brakes.

The brake holds the train by means of the foremost wagons. Owing to the steep gradient of the reception sidings the wagons close up together and the buffer springs of the front wagons are compressed. When slackening the brake, the compressed buffer springs facilitate the initial movement of the train, and will accelerate the foremost wagons. If during shunting the brakes are tightened the main part of the train will again press on to the front buffer springs and a certain amount of momentum is, so to speak, stored up. The couplings are always left loose so that the wagons can be uncoupled easily, without first having to loosen the couplings.

The time required for shunting amounts to about 5 minutes for a train of 50 vehicles which is a great success in mechanisation.

The installation works perfectly; even after the trains have been left standing for several hours in very cold weather no difficulties have been experienced. The brakes at Duisburg-Hochfeld-Süd are weight-automatic brakes of the Thyssenhütte system. They are built in the same manner as the « valley brakes » of this

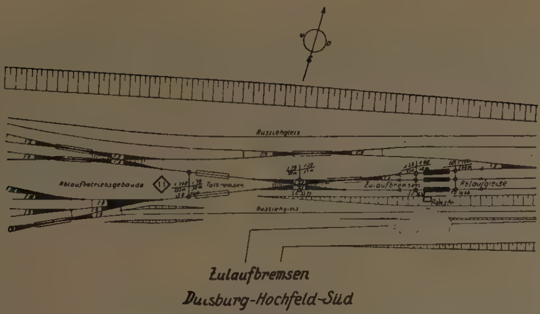

Fig. 30. — Yard with brakes near the top of the hump at Duisburg-Hochfeld (Süd).

Fig. 31. — View of yard with brakes near the top of the hump at Duisburg-Hochfeld (Süd).

type. The construction is more fully described under the head of *rail brakes*.

The advantages obtained from rope shunting or with brakes at the top of the hump are the following :

a) Cuts are made more rapidly through the exact regulation of the humping speed (control by the head shunter);

b) Continuous working, elimination of the loss of time between each train);

c) Saving of brakesmen (2 to 3 brakesmen in each shift).

IV. — Auxiliary means for regulating the shunting speed.

The auxiliary means which have been used almost exclusively in German shunting yards for regulating the speed of wagons are *rail brakes* which in most shunting yards have been designed as *skid brakes* (called « Büssing's track brake ») and in mechanised yards as distance controlled brakes.

A. — Skid brakes.

The skid brake has been installed in many yards in front of the king point, in other yards behind the first and sometimes still further back. The last mentioned arrangement requires two or more brakes, but it has the advantage of making shunting proceed more smoothly because the braking is distributed over various places. Generally, however, the number of skid brakes is arranged so that each wagon during its travel through the « danger zone » passes through one brake only.

The skid brakes serve for keeping regular distance between cuts so that they may not catch one another up, as well as for preliminary braking so that it is easier to stop the wagons in the sorting sidings.

It is a primary condition of the installation that there should be ample braking travel available, so that cuts of several vehicles can likewise receive sufficient braking.

The skid brakes consist of an ordinary skid and a throw-out device in the running track (brake frog) with a catching device for the skids which have been thrown out (see figs. 32 and 33 *a/b*). The brakesman places the skid on the running rail — at a greater or lesser distance according to the desired braking effect — from the throw-out device. One wheel of the first axle of the wagon runs on to the skid from which result approximately equal braking forces on each side of the wagon because the wheel opposite to the skid is held by the axle and in this manner also produces a braking force on the running rail. At the brake frog the skid is automatically thrown out. The entire braking force, *i. e.* the sum of the braking forces on each side, is equal to about 0.15 of the axle load, therefore with a 2-axle wagon 0.075 of the weight of the wagon. In order to deal with a height of incline of 1 m. (3 ft. 3 3/8 in.) one requires therefore 13 to 14 m. (43 to 46 feet) brake travel. With 4-axled wagons twice the distance is required. When braking large cuts very considerable brake travels are necessary according to the number in the cut and the weight of the leading wagon. Generally speaking, therefore, cuts of more than 6-axles should not be allowed to be humped without their brakes being manned.

When the skid is properly applied, it forms, an entirely unobjectional adjunct in shunting operation.

Trials with exact calculations and measurements have shown accurately the effects of the skid. It has thus been ascertained that no undue strain is put

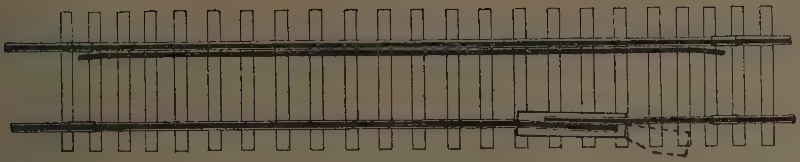

Fig. 32. — Skid rail brake (Büssing brake).

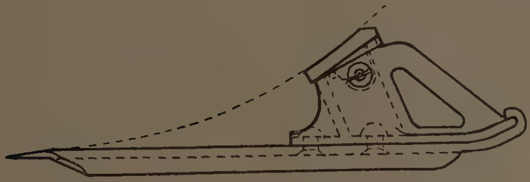

Fig. 33*a*. — Brake shoe with rivetted sole plate.

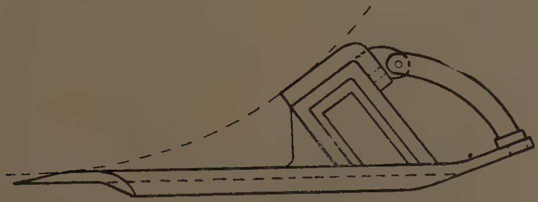

Fig. 33*b*. — Brake shoe with welded sole plate.

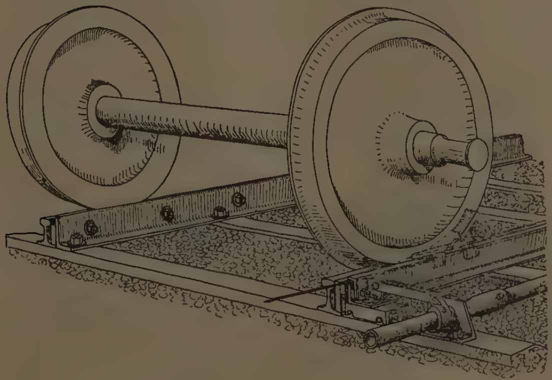

Fig. 34. — Bäseler skid rail brake.

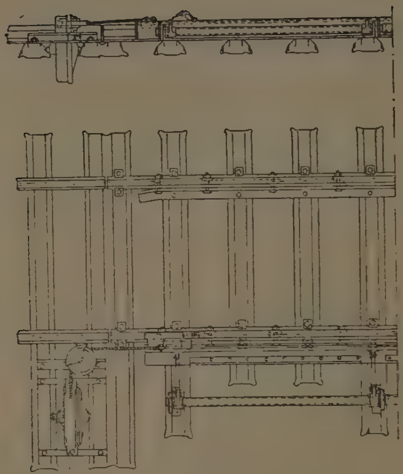

Fig. 35.
Plan view of Bäseler skid rail brake.

on the wagons by skid braking. In order to soften the impact, instructions have been given slightly to increase the sole of the skid. By doing so the jamming of the skid and consequent riding of the wheel over it are avoided. Furthermore, instructions are given that the top surface should be greased in order to keep the braked axle revolving as long as possible and prevent the formation of flats on the skidless wheel.

In order to look after the skid brakes when shunting proceeds at a good speed, the brakesman must be very skilful and experienced. His activity is rendered very much more difficult during rain and snowfall.

Therefore, efforts have been made for a long time to arrange for the skid to be controlled from a distance. At the same time it is desired to accomplish a further advantage; the distance controlled skid brake should enable the skid to be withdrawn from under the wheel so that the braking can be interrupted in the event of the brake travel having been calculated too generously.

At the Munich Exhibition of 1925 was shown the first experimental design of Dr. Bäseler, the makers being Joseph Vögele A.-G., Mannheim.

The provision of a special ramp for the wheel flange to ride on the skidless side was designed to have the effect that the braked wheel continues rolling as long as possible so that the skid may be extracted easily owing to combined friction. The skid, which is carried in a special re-engaging rail, is brought back into its initial position after the interruption of the braking (extraction of skid) by a rope actuated by a spring drum (see figs. 34 and 35).

The plant has been experimentally installed in the Munich-Laim yard, but at present it is not in action, as it has been found that the wheel cannot always be made to revolve. Special apparatus of greater power for the disengaging of the guide rail and the skid is to be provided for another experiment with this brake so that the skid can be disengaged from under a wheel even when not revolving.

The *Gesellschaft für Oberbauforschung*, Berlin, has suggested another solution which represents an improvement on the design employed at the Lille (France) yard; this system, nevertheless, does not allow of a subsequent alteration of the brake travel once the process of braking has begun.

In conclusion, it must still be mentioned that the Thyssenhütte in Hamborn has likewise tried out an entirely new type which not only permits of the interruption of the braking process, but will even permit its resumption when so interrupted. One may therefore expect that the question of distance controlled skid brak-

ing will soon meet with a satisfactory solution.

B. — Distance controlled rail brakes.

The up-to-date means for regulating the speed of wagons running freely down a hump in hump yards having much traffic, is the *distance controlled rail brake.* It will always be suitable in places where there is frequent braking and where high speeds and considerable braking forces have to be dealt with. In yards of this kind the capital expenditure is also justified.

The brakesman is released from the troublesome attendance to hand operated skid brakes. He is given a control tower which allows of a good view and protects him from the weather. With the assistance of a simple control, he can brake every wagon and every group of wagons at will and he can considerably increase or reduce within wide limits the measure of braking during the braking itself. In short, he absolutely controls the running of the wagons.

To Dr. Frölich belongs the credit of having invented the first practical rail brake. It is true that there existed a few preliminary experiments (Brosius, 1892; Willman, 1909; and Lohse, 1912) but they did not come to any practical result. Dr. Frölich thought out an ingenious principle of braking whereby the maximum of the braking effort was made dependent on the weight of the truck. He published his idea as early as 1914. The Thyssenhütte in Hamborn undertook the manufacture of the rail brake which was subsequently installed at several marshalling yards. The Transport Exhibition in Seddin near Berlin, in 1924, introduced the Jordan brake as a further novelty and at the Transport Exhibition in Munich, 1925, there was shown an eddy-current brake. The Reichsbahn, in order to encourage development, is using all these three systems.

At some of the marshalling yards only one rail brake has been built. It is placed near the winter hump at the end of the steep incline in front of the king point and it only serves for regulating the distance between cuts and for preliminary braking.

At other yards the rail brakes are placed after the king point so that in each group of tracks there is one rail brake. These rail brakes (valley brakes) serve for regulating the distance between cuts and simultaneously — with a few reservations already mentioned — for « distance braking » (braking so that the wagon will run a certain distance and stop). This method of installation has so far proved very satisfactory at high efficiency yards with suitable profiles and a favourable point layout.

The Reichsbahn, on the recommendation of the *Studiengesellschaft für Rangiertechnik* [1] has issued certain *Rules for the calculation and construction of mechanical rail brakes.* Some of these rules which are of fundamental importance may be briefly recapitulated :

1. For calculating the braking effort a friction co-efficient of 0.1 between the wheel and the rail brake should be assumed. However, 30 % should be added to the brake length required, according to this reckoning, so that the braking effort will with certainty be reached even if for certain reasons (for instance greasy tyres) the coefficient of friction should be very low.

(1) The Studiengesellschaft is a body called into being the General Manager of the Deutsche Reichsbahn and consists of five representatives each of the Reichsbahn, the interested industries, and railway experts.

2. The contact pressures must not put any material bending strain on the axles. On the rail brakes now in use two inner and two outer brake rails are arranged

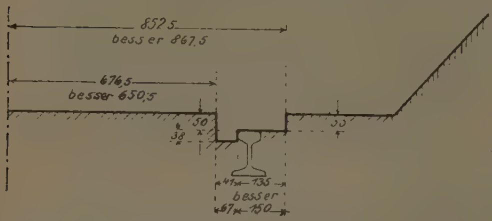

Fig. 36a. — Profile of rail brake in the « off » position.

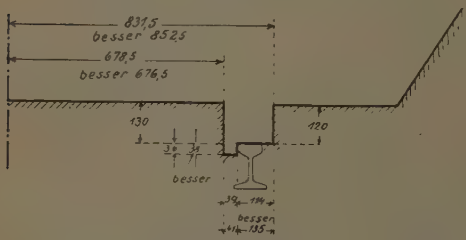

Fig. 36b. — Profile of rail brake in the « ready » position.

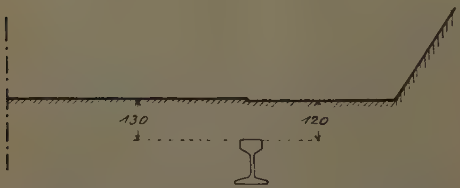

Fig. 36c. — Profile of rail brake in the « on » position.

which exert forces of equal strength so that, generally speaking, the bending effect of these forces is non-existent, but if the wheels gripped by the rail brake vary in thickness and the distance between the inner faces of the wheels is different, bending stresses can occur nevertheless. The Studiengesellschaft für Rangier Technik has established a formula which enables one to calculate with sufficient accuracy the pressure thus set up (*Verkehrstechnische Woche*, 1929, page 143). The greatest stress when conditions are most unfavourable must not exceed 1 900 kgr. per cm² (27 000 lb. per sq. in.).

3. The braking force should always be easily graduated and the time-lag of control should be short, so that the brake pressure follows the control lever accurately.

4. For the rail brakes there have been established special rail brake profiles inside which the various component parts of the brake must remain. The following distinctions are made :

a) The profile in the *off position*; the line completely coincides with the lower profile line of the permanent way profile. All vehicles can pass the brake (see fig. 36*a*);

b) Profile of the *ready position* of the brake : the portion above rail top is designed in such a manner that there still remains a clearance of 10 mm. (3/8 inch) between this profile and the wagon loading gauge. In this position wagons can pass through the brake without being braked (see fig. 36*b*);

c) The profile of the *on position : the upper* limit lines coincide with the *profile of the ready position;* the remainder which would otherwise be fouled by the wheel may, however, be used for braking (see fig. 36*c*).

5. One should endeavour to prevent automatically the possiblities of exceeding the highest admissible retardations. This retardation is at present fixed at 4.25 m. (13 ft. 11 in.) sec² in order to prevent danger to the wagons and their contents.

Fig. 37. — Marshalling yard at Hamm with four Thyssenhütte rail brakes.

The development of rail brakes is still continuing, but it must be admitted that the rail brakes installed have already shown appreciable advantages, in particular in those cases in which they have been correctly installed in track gradients and track layouts designed according to the laws of dynamics. Some advantages are :

1. Greater safety for the staff;

2. Protection of the staff from the severity of the weather;

3. Reduction of damage to wagons;

4. Increase in throughput (greater speed; reduction of the time required for closing up).

We shall now proceed to a more detailed description of the three kinds of rail brakes.

1. *Rail brake, « Thyssenhütte » type.*

The August Thyssenhütte Gewerkschaft, Hamborn a/Rh. has developed the Frölich principle of the weight-automatic rail brake into the heavy and efficient « Thyssenhütte » rail brake. The Reichsbahn first erected brakes of this type in Cologne-Nippes and Seddin as experiments. In these yards the brakes are placed *in front of the* foremost points and are used for interval braking and preliminary braking.

In the marshalling yards in Hamm (4 brakes each 19 m. [62 ft. 4 in.] long), at Duisburg-Hochfeld-Süd (3 hump brakes and 2 valley brakes each 15 m. [49 ft. 2 1/2 in.] long), and at Bremen (4 brakes each 15 m. [49 ft. 2 1/2 in.] long), the latest types of these rail brakes were erected in the central position and record

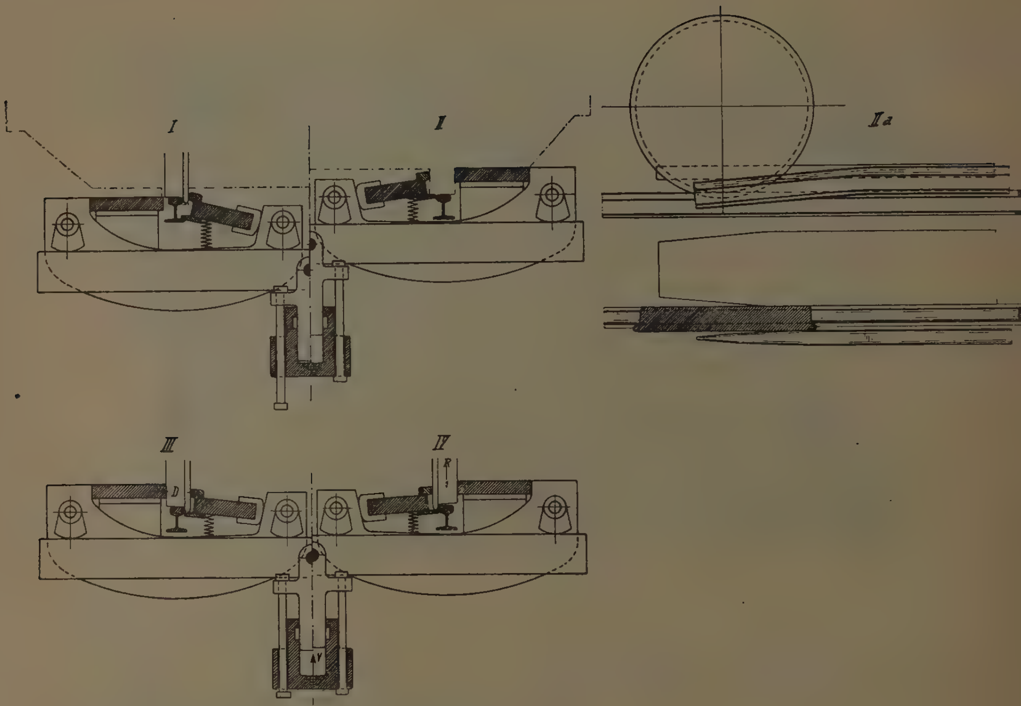

Fig. 38. — Theoretical diagram of Thyssenhütte rail brake.

figures for shunting were created. Figure 37 shows the usual position of the valley brakes, approximately in the middle of the danger zone, *i.e.* behind the first points. With this arrangement the brakes are used for interval braking and final braking. The valley brakes were used at Hamm in October 1925, in Duisburg-Hochfeld-Süd in March 1928 and in Bremen in October 1928. These brakes have been found absolutely perfect in operation. The height from the top of the hump to the middle of the brakes is 2.90 m. (9 ft. 6 in.) at Hamm, 3.10 m. (10 ft. 2 in.) at Duisburg-Hochfeld-Süd, and 4.04 m. (13 ft. 3 in.) at Bremen (winter hump). By means of these brakes the heaviest wagons and cuts of wagons of any length can be brought to a complete standstill. The brakes have ample dimensions. The speed at which the shunt can be made up to is 1.50 m. (4 ft. 11 in.) per second, which shows how successful the theory of shunting has been applied.

The Thyssenhütte brake is hydraulically actuated. By the side of each running rail there are brake rails which are fitted in cradles; the outer brake rails are fixed and the inner brake rails are supported on springs and pivoted on bearings (see figs. 38 and 39).

The cradles are movable and are sup-

ported on a horizontal girder which in the centre rests on the piston of a hydraulic cylinder to which it is flexibly joined. The girders which are placed at right angles to the brake axis at intervals of 2.60 m. (8 ft. 6 in.) are lifted hydraulically by water led through pipe lines. When the brake is lowered all vehicles can pass through it (see part I of theoretical sketch, fig. 38). In the « On » position provision is made for limiting the lift so that the profile of the « On » position is not exceeded (see part II of the theoretical sketch, fig. 38).

The braking effort is produced by the wagon running on to the foot of the movable inner brake rail (see part II*a* of the diagram, fig. 38) and by the weight of the wheel being wholly or partly converted by the inclined position of the inner brake rails into a horizontal contact pressure of the brake rails against the wheels (see part III of the diagram, fig. 38). The contact pressure is limited whilst the vertical pressure (lifting force) which is controlled and which has been converted into a horizontal contact pressure, can never become greater than the axle load of the vehicle. The control pressures exceeding this are taken up by lift stops, the wheel being slightly lifted from the running rails (see part IV of the diagram, fig. 38).

In normal working the necessary braking effort is obtained with pressures (lifting force) smaller than the axle load. The difference between the axle load and the lifting pressure is then taken up by the running rails.

The rail brake is housed in an iron under-structure (see figs. 40 and 41) which renders concrete foundations unnecessary. The iron understructure which rests on sleepers and ballast, enables it to be speedily erected and thoroughly inspected when in operation.

Brake control is effected by actuating the control valve from the control tower (see figs. 42 and 43). Each brakesman can attend to two brakes. The hydraulic power is supplied by two motors for the pump and a water accumulator.

2. *Jordan rail brake.*

The Reichsbahn has experimentally installed two brakes of the Jordan Brake Co., Berlin-Neukölln, for « interval » and « preliminary » braking. In the marshalling yard at Wustermark near Berlin there is a rail brake 12 m. (39 ft. 4 1/2 in.) long and at Arnsdorf near Liegnitz one of 16 m. (52 ft. 6 in.); the latter is in two halves and joined in the centre. Both brakes are situated on the winter hump.

The rail brakes at Wustermark were put down in March 1926 and figure 44 illustrates the position of the brake in front of the king point.

The rail brake at Arnsdorf was put down in September 1927; figure 45 illustrates the brake, the brake tower and the control tower.

The height of the hump at Wustermark is about 3.90 m. (12 ft. 10 in.) and at Arnsdorf, 3.20 m. (10 ft. 6 in.).

The Jordan rail brake is actuated by *compressed air*. On both sides of the running rail there are placed brake girders which are carried on roller bearings by horizontally placed supporting girders. So that the brake may be lowered, the girders can slide vertically by means of movable frame construction on both sides, which are guided in a solid vertical frame and are supported on the rollers of the lifting rods. To each of the lifting rods, which are inter-connected by means of stays and levers, two *lifting cylinders* are connected by means of levers.

Between the double channel bars of the horizontal supporting girders there are

Fig. 39. — View of a Thyssenhütte rail brake.

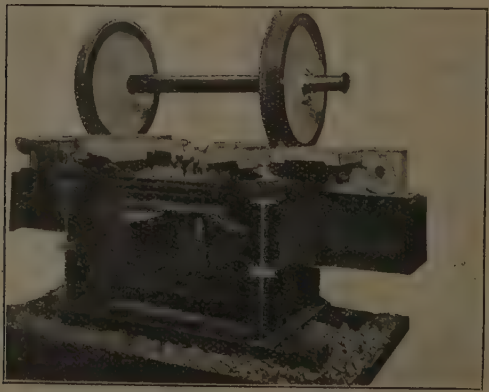

Fig. 40. — Cross section of a Thyssenhütte rail brake.

arranged steel castings which guide the brake girders and which are fitted with crank shafts. Each shaft is actuated by a lever keyed on the lower shaft, the position of which lever is changed by the piston of the brake cylinder located under each supporting girder. Altogether there are thus arranged under each supporting

Fig. 41. — Laying down a Thyssenhütte rail brake.

girder 4 *brake cylinders* and figure 46 shows a cross section through the rail brakes, whilst figure 47 shows the roller bearing of a brake girder.

When in the « off » position any vehicle may pass over the brake without obstruction.

When in the « on » position the brake rails are under a pressure which can be regulated. The wheels of the vehicles open the brake rails and in doing so are subjected to a contact pressure which varies with the amount of pressure applied. An electric device is provided in order to prevent the wagons riding on the rails and becoming derailed, by means of a track circuit which releases the compressed air as soon as the wagon begins to ride the rails.

Brake control is effected by actuating the control switch (control valve) from the brake tower (see fig. 48). The necessary compressed air is supplied by a compressor.

The trials which have been made with the Jordan rail brake have shown that great braking forces can be produced with safety. The heavy rail brakes work very quietly.

An absolutely efficient protection against the derailment of light vehicles which are subjected to very great braking forces however, has not yet been obtained by the electrical safety device. The

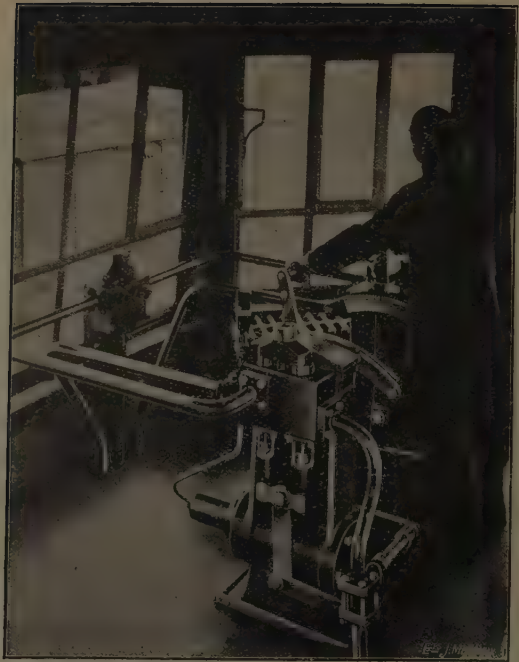

Fig. 42. — One man operates two Thyssenhütte rail brakes.

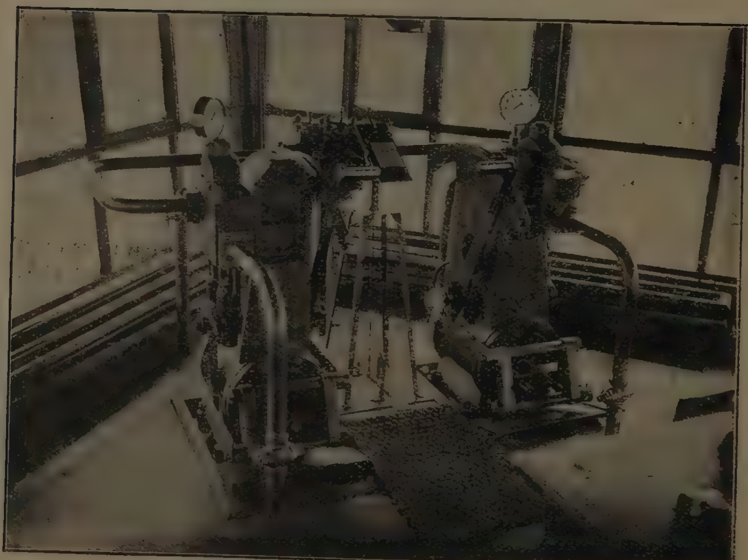

Fig. 43. — Operating stand of Thyssenhütte rail brake.

Fig. 44. — Jordan rail brake in Wustermark marshalling yard.

Jordan Bremsen Gesellschaft has therefore revised this type of brake and has brought out a weight-automatic brake which is controlled by compressed air; experiments with this brake in the form of a one-sided rail brake are to be made at Wustermark.

3. *Electro-magnetic brake.*

The first experimental type of electromagnetic rail brake designed in accordance with the inventions of Dr. Bäseler and Professor Thoma was shown at the Transport Exhibition in Munich. The experiments with this original exhibit as well as detailed calculations and experiments with models showed such favourable results that the Reichsbahn decided on having a rail brake of this type constructed.

In the marshalling yard at Magdeburg-Buckau, the Gesellschaft für Oberbauforschung, Berlin, installed a 12 m. (39 ft. 4 1/2 in.) electro-magnetic rail brake (on the winter hump) for interval and advance braking. It was laid down in December 1928. Figure 49 shows the brake, situated underneath the bridge signal box; figure 50 gives a view of the shunting yard at the winter and summer humps with signal box (Br.) and brake tower (Blg.); figure 51 shows the brake in action.

The movable brake rails of the electromagnetic rail brake, which are parallel running poles, are joined to the pole rails of several electro-magnets (see figs. 52 and 53). The running rail is made of non-magnetic non-wearing hard steel.

The brake rails are composed of a number of iron plates, steel pieces being fitted on the braking surfaces. They rest on

Fig. 45. — Jordan rail brake with control tower (brakes and points) in Arnsdorf marshalling yard.

groups of iron plates loosely placed side by side, so that the brake rails easily adapt themselves to tyres of varying thicknesses. The groups of plates form the connection between the brake rails and the electro-magnets below the running rails in the centre of which there is an exciting coil enclosed in a metal box which is made waterproof by welding and soldering; all spaces are filled up with insulating material.

The magnetic flux passes from the poles of the magnetic cores to the plates and returns through the brake rails. The lines of force are then cut by the wheels of the vehicle (massive bodies of metal) and cause eddy currents. The latter produce a power component which acts contrary to the existing motion so that the eddy current results in a braking effect. By the consequent strengthening of the lines of force in such places where tyres are between the brake rails there also occurs a considerable increase in the magnetic

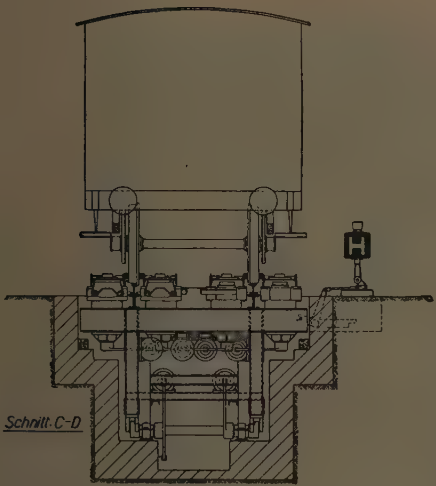

Fig. 46. — Cross section through Jordan rail brake.

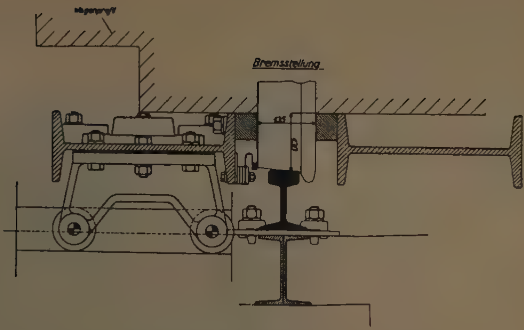

Fig. 47. — Roller bearing of a rail brake.

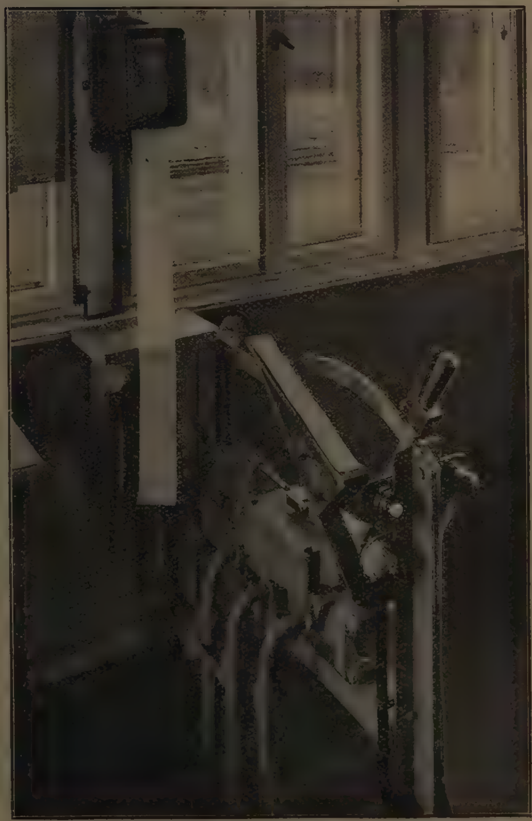

Fig. 48. — Operating stand of the Jordan rail brake.

pressure and thus in the friction between the brake rail and tire. The braking effect is therefore composed of an eddy current braking effort and a friction braking effort. Of this braking effort 2/3rds belong to the eddy current effect and 1/3rd to friction. The brake rails thus only suffer little wear.

For the excitation of the brake direct current of 220 volts is required. When the circuit is closed the brake rails approach as far as a spring stop. The vehicle entering the brake opens the rails easily because the pressure remains very small whilst there is no wheel between them.

The brake rails can be lowered to the « clear » position.

Control is exercised in the simplest manner by operating the regulator from the brake tower.

The brake functions faultlessly; the working expenses (cost of current) with the existing design are rather high owing to the use of a rotary converter. The

Fig. 49. — Electro-magnetic rail brake at Magdeburg-Buckau.

Fig. 50. — Electro-magnetic rail brake and brake tower at Magdeburg-Buckau.

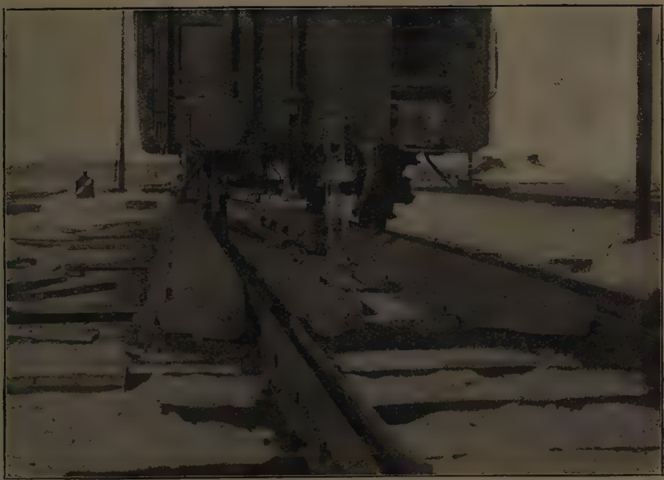

Fig. 51. — Electro-magnetic rail brake in action.

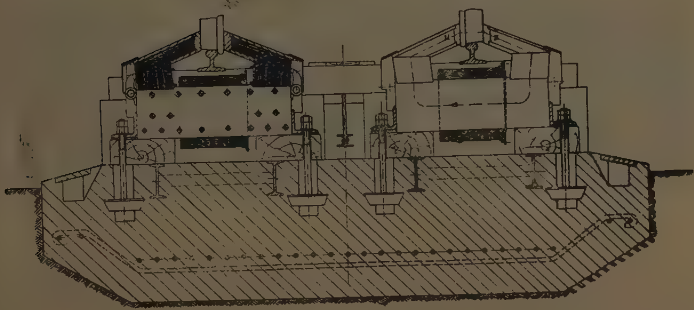

Fig. 52 — Cross section trough electro-magnetic rail brake.

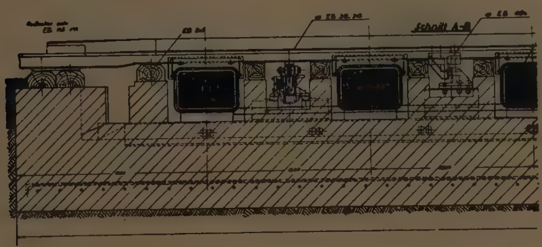

Fig. 53. — Longitudinal section through electro-magnetic rail brake.

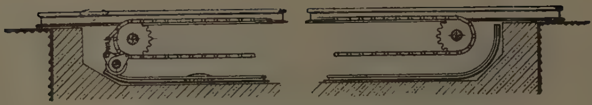

Fig. 54. — Diagram of « Pösentrup-Heinrich » accelerator.

Fig. 55. — View of accelerator.

height of the hump is 2.28 m. (7 ft. 6 in.). The braking power is sufficient.

C. — **Accelerating devices.**

As mentioned in an earlier section, the Reichsbahn has also experimented with an accelerating device which is called the Pösentrup-Heinrich Accelerator after its inventors. The object of this appliance is to make a comparatively low hump suffice and to add by additional acceleration the kinetic energy which the *bad runners* need to make them pass through the danger zone as quickly as the *good runners*.

The first experimental installation (length 7.50 m. [24 ft. 7 in.]) was made in 1924 at the marshalling yard of Seddin. A new installation (length 10 m. [32 ft. 10 in.]) was opened in February 1929 at Osnabrück.

The contractors were the Gesellschaft für Oberbauforschung, Berlin.

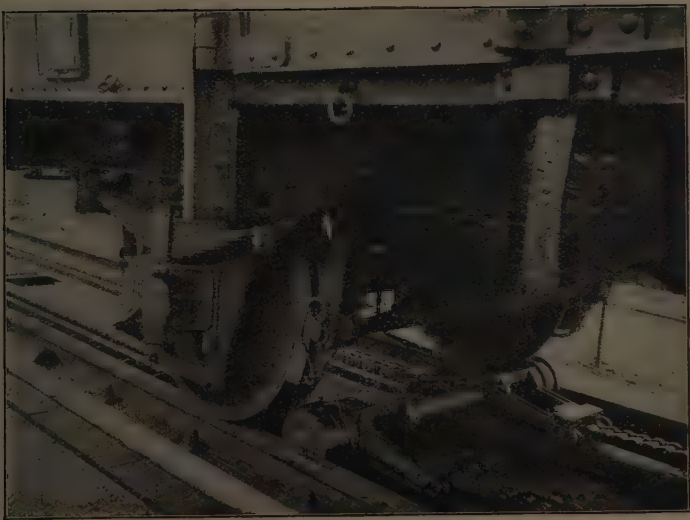

Fig. 56*a*. — Driving axle of accelerator in action.

The accelrator consists of a sledge which moves in between the rails : this sledge is driven by means of an endless chain having an initial tension of about 1 800 kgr. (3 970 lb.) (see figs. 54 and 55). The sledge is guided by means of rollers on special rails and at its extremities, close to the running rollers, carries gripping blocks which grip the flanges of the wheels (see figs. 56 *a/b*).

The sledge thus exercises a pressure and pushes the wagons forward. The sledge returns to its « off » position (position of readiness) through a pit underneath the track. On the return the gripping blocks carry the sledge because their direction of rotation remains the same when running back.

The accelerator has a control lever which automatically adapts the starting speed of the sledge to that of the wagon so that it makes contact with the wheels without shock (see fig. 57).

The main drive has a Jordan slip-clutch, oil-cooled and actuated by compressed air.

The installation is made about 10 m. (32 ft. 9 3/4 in.) below the top of the hump. Its maximum throughput corresponds to an additional incline of 2 m. (6 ft. 6 3/4 in.) for a 10-ton wagon. The maximum speed of the sledge amounts to 7 m. (23 feet) per second. The duration of acceleration is 10 seconds.

If the head shunter wishes to accelerate a wagon, he first presses a « permissive key ». The control circuit is, however, only closed when one axle passes over a wheel contact. As soon as the sledge touches the flanges with its gripping rollers, the yard master can regulate the acceleration of the wagons within defined limits.

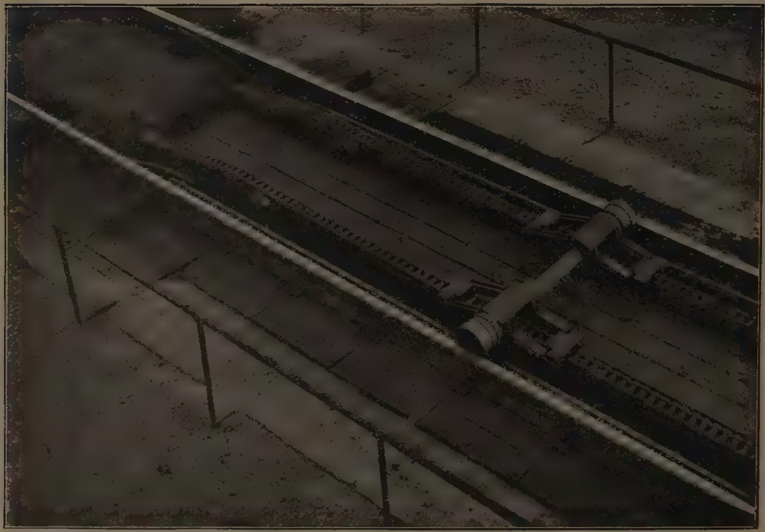

Fig. 56b. — Driving axle (view).

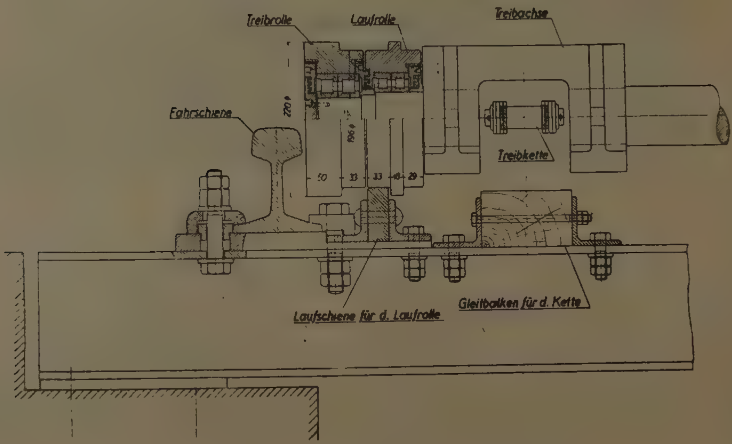

Fig. 56c. — Cross section through driving axle.

Explanation of German terms: Fahrschiene = Track rail. — Gleitbalken fur d. Kette = Guiding beam for driving chain. — Laufrolle = Running roller. — Laufschiene für d. Laufrolle = Rail carrying running roller. — Treibachse = Driving axle. — Treibkette = Driving chain. — Treibrolle = Driving roller.

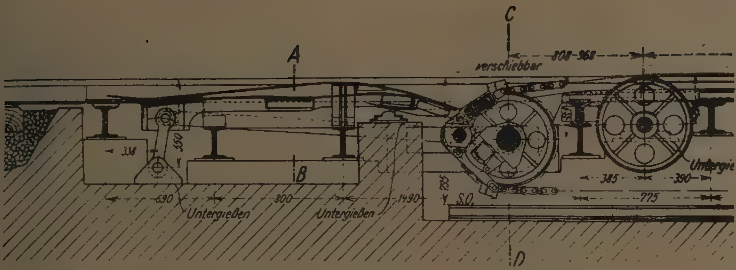

Fig. 57. — Control lever at front end of accelerator.

The installation is still in the experimental stage and it is too early to arrive at a final opinion of its value.

Similar drives are principally suitable in those cases where difficulty is met in increasing the height of humps and where the shunting speed has to be improved by additional machinery without considerable constructional alterations. In older yards where points are some distance from the hump it will be possible to avoid the wagons stopping, a feature which during unfavourable weather conditions badly interferes with the shunting operations.

V. — Means for ensuring correct running of the wagons.

A. — Means for informing the staff.

For the purpose of giving reliable information to all the staff concerned with the shunting of the trains a *shunting list* is issued (see fig. 58).

It consists of one or more *cut cards* which indicate the various cuts with the number of wagons and their destination sidings and an *allocation list* which, besides the number of wagons, mentions the number of the skid layer into whose area the wagon will come.

The object of the *allocation lists* is to determine into which skid layer areas the various cuts will arrive, and to release staff for other purposes by a special allocation of the wagons (so that special wagons and large cuts may be manned).

The shunting lists are made up by a shunter and are confirmed by the head shunter who enters them up. It is manifolded according to requirements.

The shunting list contains all the information of importance for the shunt. For instance, special marks will indicate whether trucks are empty or loaded, whether any dangerous wagons or particularly *bad runners* are included, and whether or not the wagons are equipped with serviceable hand brakes.

The method of transmitting the lists to the staff concerned varies according to local conditions.

The head shunter and the foreman of the skid layers in the direction sidings are given an *allocation list*, the other men (foremen, pointsmen, skid layers and driver of the humping locomotive) receive a shunting list.

The foreman at the foot of the hump ascertains from the *allocation list* which orders he will have to give to the skid layers.

The pointsmen mark the cuts which do

Cut No.	Date 23/3 Train 8751 From track 22 — Number of wagons	Track	Cut No.	Date 23/3 Train 8751 From track 22 — Number of wagons	Track	Cut No.	Date 23/3 Train 8751 From track 22 — Number of wagons	Zone of skid brake application. Tracks. 1	2	3	4	5	6	7	8
1	1	32	1	1	32	1	1	32							
2	00	37	2	00	37	2	00			$\boxed{II}$					
3	1	32	3	1	32	3	1	32							
4	11	31	4	11	31	4	11	31							
5	0	52	5	0	52	5	0								52
6	0	49	6	0	49	6	0							49	
7	V ⊗	34	7	V ⊗	34	7	V ⊗		$\boxed{34}$						
8	6 ⊗	47	8	6 ⊗	47	8	6 ⊗						47		
9	1	52	9	1	52	9	1								52
10	00	40	10	00	40	10	00				40				
11	0S	33	11	0S	33	11	0S	33							
12	11	38	12	11	38	12	11			$\boxed{38}$					
13	10	31	13	10	31	13	10	31							
14	9 ⊗	47	14	9 ⊗	47	14	9 ⊗						47		
15	VV ⊗	46	15	VV ⊗	46	15	VV ⊗						46		
16	1	39	16		39	16	1				39				
17	1	53	17	1	53	17	1								53
18	4 X	48	18	4 X	48	18	4 X							48	
19	1	51	19	1	51	19	1								51
20	00	31	20	00	31	20	00	31							
21	10	40	21	10	40	21	10				40				
22	00	35	22	00	35	22	00		35						
23	1	50	23	1	50	23	1							50	
24	1	47	24	1	47	24	1						47		
25	11	46	25	11	46	25	11						46		
26	**The end.**		26	**The end.**		26	**The end.**		B	B		B	B		
27			27			27			(7)	(14)		(15)	(8)		

1 **List of cuts.** 2 — **Allocation list.**

1 = 1 loaded wagon.
11 = 2 loaded wagons (III = 3 etc...).
0 = 1 empty wagon.
00 = 2 empty wagons (000 = 3 etc...).
10 = 1 loaded wagon (in front) and 1 empty wagon.
II (7) = Skid brake operator has to work the brake of cut No. 7.

V = 1 test wagon (Vorsichtswagen) (*V V* = 2 etc...).
S = Bad runner (Schlechtläufer).
X = 1 hand brake can be made use of (XX = 2 etc.)
⊗ = 1 hand brake manned.
4 X = Group of 4 wagons which have to run down separately, it being impossible to work the brake.

Fig. 58. — Shunting list.

not concern their area beforehand, and during the shunt cancel the various cuts one by one.

B. — Control towers.

The control towers are of particular importance for observing the wagons during the shunt.

Generally the point levers of the distribution points are brought together in groups and housed in control towers. As regards the method of doing this, various shunting yards differ considerably.

With distant operation of the points by means of a wire or rodding, the number of levers to be operated by one man must not be too great on account of the close succession of wagons. Since it is furthermore necessary that the pointsmen should be able to supervise their areas well, three or more control towers have in many cases been provided for *one* hump yard.

In other cases it has been considered more convenient for the sake of easier communication and the better employment of the staff, to bring together all point levers in one control tower. This tower is usually built on raised ground so as to secure a good view. In misty weather (fog, etc.) the view, however, remains imperfect, particularly in the case of distant points. Therefore in some cases the levers of the first points have been taken from the shunting control tower and allocated to the yard master on the hump. The advantage thereby is that the shunting control tower is placed in a more favourable position as regards its points because it can be moved farther away from the hump.

The introduction of electrically-controlled points materially facilitated the grouping of the points in *one* shunting control tower. In a great many cases the control tower was placed on a bridge across the shunting tracks. This gave at the same time a good view of the points in the reception sidings connected with the hump. For this reason they were included in the control tower with a consequent further economy in staff and a greater ease of co-operation.

However, this arrangement is not entirely satisfactory. In misty weather the visibility is not sufficient because the distance between the control tower and the farthest points is too great. In addition, the control tower on the bridge has an adverse effect because when the wind is unfavourable, it is deflected under the bridge and meets the descending wagon with increased force. This method has therefore been lately discarded, the design of automatic point operation having influenced the decision.

Automatic point operating apparatus.

Automatic point operating apparatus made it possible to control automatically the point operating gear. The point operating gears are operated and controlled by the wagons — the point movements being prepared before the beginning of the shunt.

In this way there were obtained, besides a number of advantages which will be explained later, two which signify distinctive progress :

1. Point occupation was reduced to a minimum.

2. It was now possible to place the point operating apparatus in its correct position, *i. e.*, amongst the points it operated (see figs. 8, 15*a* and 37) because the points at the back of the point operator could be made automatic.

The first attempt to produce such an installation was made in 1914. The basic idea of the first installation which Messrs. Siemens & Halske, Berlin, (S. & H.) built,

consisted in allocating to each track a series of relays connected by track circuits to the individual points. The wagon throws its points just before it passes over them. To the Allgemeine Elektrizitäts Gesellschaft, Berlin (A.E.G.) belongs the credit of having demonstrated in a practical manner the idea of storing up the point movements, *i. e.*, the setting up in advance of each route through which the train to be shunted had to pass. Siemens & Halske brought out another design soon afterwards. Both designs are now being manufactured by the Vereinigte Eisenbahn Signalwerke, Ltd., Berlin-Siemensstadt.

The following advantages can be obtained with automatic point operating apparatus :

1. *Grouping into routes :* Instead of the many levers which are necessary for the operation of the point levers of an ordinary control tower for setting up a route, the operator now has to move only *one* handle for each cut in order to set the automatic points for that route.

2. *Setting of the points just before the train is shunted is no longer necessary :* The moment at which the operation is carried out does not matter within certain limits, because the route is first stored up in a « collector drum ». This device allows all the routes — where automatic points are in use — to be set up in advance before the train commences to be shunted.

3. *Automatic throwing of the point :* The « automatic points » are thrown whenever necessary by the wagons themselves for which purpose quick operating point gears are in use.

4. *One-man operation:* Besides generally observing the shunting of the wagons the point operator has only to attend to the non-automatic points. If the sidings are well laid out 80 % of all point movements take place at the automatic points. The operation of the points has therefore become simplified to such an extent that one man can attend to all the remaining points without difficulty.

5. *Convenient switch table :* All the point switches are generally arranged on an inclined switch table in such a manner that the levers are within reach of the point operator without his having to move. The layout of the track is diagrammatically reproduced on the switch table and the hand switches are placed at the points where the tracks diverge which makes it easy to locate them (see figs. 59, 60 and 61).

6. *Observation by colour lights :* A small lamp at each point switch indicates the occupation of the point so that the movements of the wagon can be followed on the switch table — apart from the fact that the wagons themselves can be seen.

A. E. G. control tower.

A collector drum actuated by a series of selector rods is provided for storing up the automatic setting and throwing of the points. The selector rods for each route are actuated by a lever from the switch table, and operate the collector drums. For each automatic point there is one collector drum (see fig. 62).

The latter consists of a drum which stores up the point movements in advance and of a wheel which at the right moment actuates the movements of the point operating gear. Both drum and wheel are mounted on the same shaft, the wheel being inside the drum.

Each wagon when passing over a point operates by means of an insulated rail and relay the corresponding collector drum

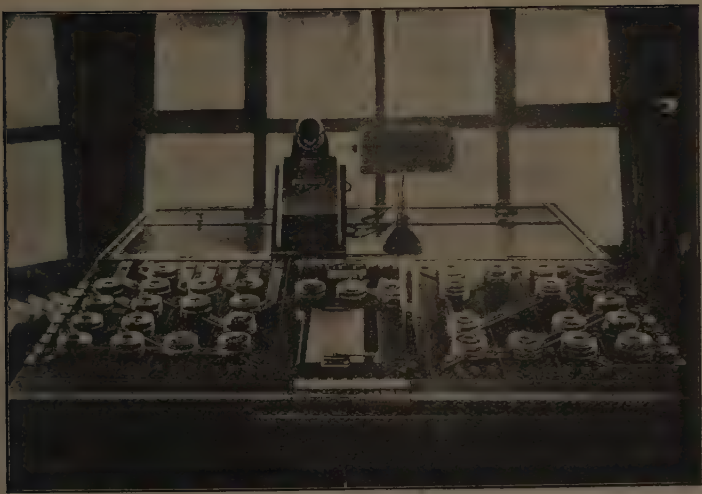

Fig. 59. — Switchboard (A. E. G. type) at Hamm.

whereby the point, after being released, automatically resets itself for the next wagon passing over it. If it is necessary for the point to be in the same position for the next cut no alterations will take place.

The A.E.G. control apparatus is fitted at *Hamm* for 52 points of which 8 are automatic (laid down in November 1925); at *Arnsdorf* there are 30 points of which 5 are automatic (laid down in August 1927) and at *Duisburg-Hochfeld-Süd* there are 52 points of which 9 are automatic (laid down in March 1928). At *Osterfeld-Süd* an apparatus of this type is now under construction (46 points of which 8 are automatic).

The S. & H. control apparatus.

The S. & H. control apparatus is electrically operated throughout. The preparatory « impulses » are collected in a so-called « route collector » (see fig. 63). For each route the operator presses one key on the keyboard which has as many rows of key switches as there are impulses to be collected. Each of these key switches has as many keys as there are routes. This installation has the advantage that all impulses which have been collected remain visible so that a cut may be altered at any time before the vehicle passes over the insulated rail of the first point. The switching operations which become necessary when a wagon passes through the automatic point zone are begun by a « pitch switch » and are automatically completed by relays (magnetically controlled contacts). Each point has a switching device which is able to receive the impulse necessary for an approaching wagon to set the point in the desired position and to transmit an impulse to the next point either directly or through an intermediate

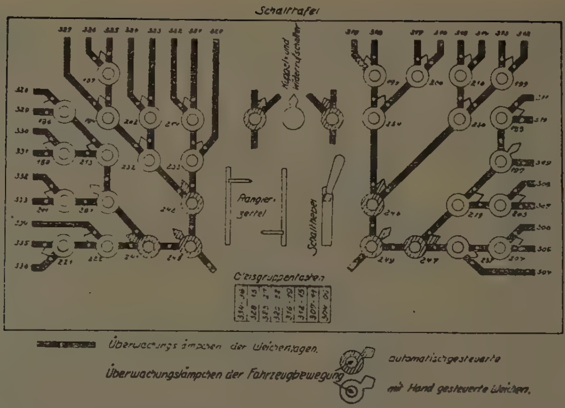

Fig. 60 — Switchboard wiring diagram.

Explanation of German terms: Schalttafel = Switchboard. — Kuppel- und Widerrufschalter = Coupling and cancelling switch. — Rangierzettel = Shunting list. — Schalthebel = Switch lever. Gleisgruppentaste = Route keys. — Überwachungslämpchen der Fahrzeugbewegung = Control lamp of wagon movement. — Überwachungslämpchen der Weichenlagen = Point occupation lamps. — Automatischgesteuerte = Automatic points. — Mit Hand gesteuerte Weichen = Hand worked points.

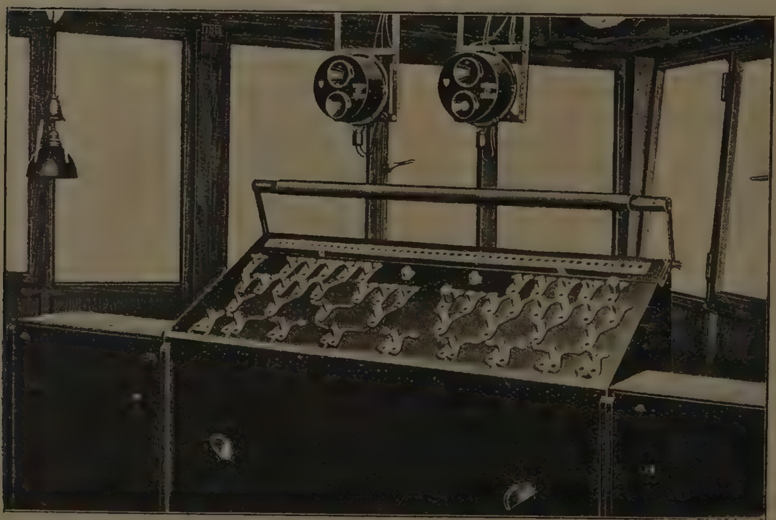

Fig. 61 — Siemens & Halske switchboard at Bremen.

Fig. 62. — Collector drum of automatic gravity shunting tower (A. E. G. system).

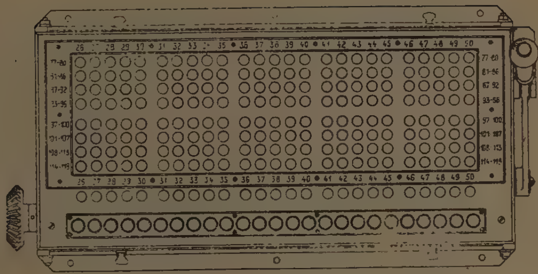

Fig. 63. — Collector drum of automatic gravity shunting tower (Siemens & Halske system).

switch. Therefore each wagon when passing over a point brings the next point into the desired position; the point can only be thrown when it is not occupied.

The S. & H. control apparatus has been fitted at *Bremen* for 44 points of which 8 are automatic (laid down in 1928), and at *Dittersbach* for 73 points of which 7 are automatic points (laid down in March 1928).

VI. — Means for closing up the wagons in the sorting sidings.

The sorting sidings serve for the reception of wagons and groups of wagons from the trains which have been split up in the shunting operations. The number of sidings differs in the various marshalling yards. As a rule it is determined by the number of destinations and the use for which the wagons of the shunted trains are intended.

The sorting sidings have a length of 400 to 800 m. (1 312 to 2 624 feet) or more. In the older yards they are frequently too short, the disadvantage of which becomes particularly noticeable when the trains depart directly from the sorting sidings. In more recent yards the sorting sidings have therefore been made of greater length.

On gravity shunting yards the sorting sidings have a continuous down gradient of about 1 : 100. If the wagons do not immediately leave the sidings they are made up into larger groups and kept together by hand-braking a few of the wagons.

In non-accelerating yards the sorting sidings are built with a slight down gradient of 1 : 400 to 1 : 800 or less. This incline tends to keep the wagons close together and so facilitates the coupling-up operation.

For new installations it is advisable to choose a gradient according to circumstances. In the case of valley brakes for instance, which should not be placed too far from the sorting sidings (at the most about 100 m. (328 feet) and which have to

bring the wagons to a stop at the required distance, if it is necessary for all wagons to be brought to a stop anywhere within a defined area of the sorting sidings (destination area) the most suitable profile for the sorting sidings must be determined according to the position of such « destination area ».

Should the sorting sidings commence only at a certain distance behind the last danger signal (signal showing to what extent the roads are occupied (for instance 50 m. [164 feet]) which, with sufficiently long sorting sidings and a high hump can be safely recommended, it appears expedient to carry the level portion which must begin soon after the valley brakes, up to this point. This layout increases the advantage which the level front area behind the brakes offers, *i. e.* wagons which have been braked for destination will run more uniformly because those which have been braked for a near destination must still leave the brake at a comparatively high speed in order to arrive at their destination.

However, a gradient of 1 : 500 to 1 : 350 is advantageous in the sorting sidings because then the speed of a wagon braked for a *far* destination point need not be so much in excess of that of a wagon braked for a near destination, as would be the case when the sorting sidings are on the level.

In the case where a large number of empty wagons must be handled and there is frequently a head wind, the incline may be greater than in the case where there are mainly heavy loaded wagons to be shunted with a following wind.

The incline must, however, not be so great that « destination braking » becomes uncertain or that wagons begin to move by themselves. The last part of the sorting sidings should, for the sake of safety, be again on the level.

When the wagons have come to a standstill there will be spaces left between them. Even with the faultless « destination braking » of modern plants these gaps cannot be avoided because the brakesmen cannot work so exactly that the buffers of one wagon shall only gently touch those of the preceding one.

The wagons must, therefore, still be pushed together in order to be ready for coupling-up. The groups of wagons thus formed are either taken to the departure sidings (or to the station order sidings) or they depart directly from the destination sidings as completed trains.

A high throughtput can only be attained if the necessary shunting operations in the sorting sidings keep pace with the work done at the top of the hump.

In the older installations with long point zones and comparatively low humps the wagons often stop too soon. The sorting sidings therefore become full up in the front portion and operations must be interrupted.

Generally, therefore, a locomotive coming from the direction of the hump, must, after one or two trains have been shunted, push the roads down. This has to be done on each track, takes up a considerable amount of time and always means a great interruption in the shunting operations.

In the newer layouts with their comparatively good « destination braking » it is necessary for efficient shunting, to push the roads down from time to time.

When this becomes necessary, the trains which leave the sorting sidings direct as completed trains are pushed together ready for coupling-up in one operation. With all other groups of trains, it is generally sufficient to push the wagons only so far as it is necessary for shunting operations. The shunting engine which

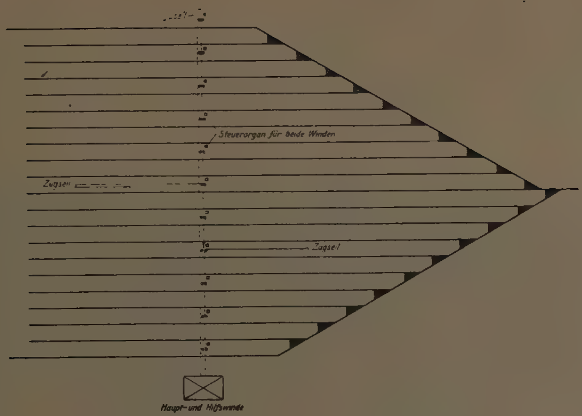

Fig. 64. — Principle of rope-winch (Bäseler system).

Explanation of German terms: Hilfseil = Auxiliary rope. — Zugseil = Drag rope. — Control device of both winches. — Haupt und Hilfwinde = Main and auxiliary winch.

draws these groups of trains out from the other end pushes the entire train together for coupling up.

The customary method of pushing down the roads with a shunting locomotive always entails a loss of efficiency in the shunting operations which is still more apparent with old layouts than with up-to-date ones.

Efforts are therefore now being made to devise some scheme to close the wagons up together ready for coupling-up *without* interfering with the shunting operations, so that a high shunting throughput is obtained by really continuous working.

In the past, two similar kinds of « closing-up » devices have been in use in the sorting sidings :

1. A rope winch.
2. A pushing truck.

Rope winch.

A rope winch (Bäseler system) was put in operation at Munich-East in the month of March 1927; this was supplied by the firm of Ernst Heckel Gesellschaft für Förderanlagen, Saarbrücken.

Stationary engines are used as prime movers for the distant controlled trackless shunting winch; one main winch (12 H.P.) with a tractive effort of 1 500 kgr. (3 307 lb.) at 0.40 m. (1 ft. 3 3/4 in.) per second rope speed, also one auxiliary winch (2 H.P.) and one winch gear (1.3 H.P.). The main rope and the auxiliary rope are coupled and run in grooved rollers in a channel at right angles to the direction of the track in such a manner that the auxiliary rope brings the main rope to the desired position, where, after uncoupling, it is ready for use. The winch gear moves the winch drum when the drag rope is being drawn out. For 20 sidings there are 11 double sided rope rollers with 11 push button controls. Each control is connected to the motors and control apparatus in the engine room. The working distance of the drag rope amounts, when twice drawn out, to about 300 m. (984 feet) (see fig. 64).

The drag ropes are drawn out by hand.

Fig. 65. — Pushing truck crossing shunting lines.

The arrangement of placing the control apparatus and rope gear between every second track makes it possible to attach the drag rope to the wagons at any desired spot without interfering with shunting operations. With an operating radius of 300 m. (984 feet) it is possible to keep the most important part of the sorting sidings *i. e.*, the part near the hump, clear for shunting operations.

The working speed is comparatively low and there are long intervals between the various operations.

The plant is still in its experimental stage.

Pushing truck.

At *Magdeburg-Rothensee* there was put into operation in January 1928 a « pushing truck » driven by accumulators and running on a narrow gauge track. The idea emanated from Mr. Leibbrand, Director of the Reichsbahn. The installation was made by the Reichsbahn District Administration at Magdeburg, and the suppliers of the truck were the Siemens-Schuckert Works in Berlin.

There are 25 sorting sidings and between every two tracks there is a narrow gauge track of 76 cm. (2 ft. 6 in.) gauge;

in all there are 13 tracks of about 10-km. (6.2 miles) length. These tracks terminate in dead ends in the direction of the hump, whilst at the opposite end of the sidings they are joined together by 1 : 7 turn-outs and end in 2 tracks so that the truck can travel from one narrow gauge track to another : of course in doing so it crosses the sorting sidings.

The truck is 6.37 m. long (20 ft. 10 in.), 1.04 m. (3 ft. 5 in.) wide and 1.15 m. (3 ft. 9 1/4 in.) high, with a wheel diameter of 750 mm. (2 ft. 5 1/2 in.), total working weight 9.8 tons, with 2 direct-current motors of together 18 H. P. There are two accumulators. The speed of the truck when loaded is 6 km.(3.7 miles) per hour and when empty 14 km. (8.7 miles) per hour. As regards tractive effort, the truck develops 750 kgr. (1 653 lb.) at 6 km. (3.7 miles) per hour. When starting, up to 1 750 kgr. (3 858 lb.) has been measured at the drawbar. With this, as experiments have shown, loads of 150 to 200 tons can be moved and moving loads up to 500 tons can be kept moving. Each truck is manned by two men : one driver and one coupler (see fig. 65).

The installation gives the advantage that the wagons which have been shunted can be closed up in the forward direction, ready for coupling, and the sorting sidings are kept clear at the hump end. The installation works well, the wagons can be dealt with carefully, and the number of wagons damaged in shunting has been materially reduced.

A « pushing truck » is particularly suitable for sorting sidings from which the trains depart direct, because in this case the wagons do not have to be moved by locomotive power from the time they are humped until their departure.

* * *

In conclusion it should also be mentioned that at the present time an experiment with a trackless motor tractor in a small group of sidings is being proposed. The dimensions of the tractor will be small and kerbs will be provided on both sides of its path to prevent it fouling anything.

Careful calculations by the Studiengesellschaft für Rangiertechnik show that tractors with or without tracks can only claim to be an economical proposition when a large number of wagons has to be dealt with, but in these instances, they become an indispensable and economical auxiliary for increasing the efficiency of a marshalling yard.

SUMMARY.

1. There are two reasons which can justify the mechanisation of shunting yards :

a) the desire to lessen the cost of the shunting operations;

b) the necessity for increasing the throughput.

2. An increase in the throughput becomes necessary :

a) on account of an increase in traffic;

b) when the work of the train-formation must be concentrated.

3. A very high throughput in a shunting yard can only be obtained if :

a) the trains can be shunted quickly;

b) unavoidable delays are kept down to a minimum;

c) the necessary shunting operations in the sorting sidings do not interfere with the main shunting operations.

4. Trains can only be quickly shunted if :

a) the hump is sufficiently high;

b) the profile of the gradient is suitable:

c) efficient rail brakes are used;

d) the position of the points is carefully arranged;

e) the period of point occupation is small;

f) the humping speed can be exactly regulated.

5. The following principles can, therefore be applied to yards with a *high throughput* :

a) The hump must be at least so high that a bad runner in unfavourable weather will run past the point zone, and will still run for a certain distance into the sorting sidings;

b) the gradient profile should begin with a steep incline, the drop of which should be about equal to one half the height of the hump, and should then pass into a smaller gradient. Thereafter the necessary gradient depends upon the position and number of brakes.

If there is only *one* set of brakes, that is for « interval braking » and « distance braking » the point zone should be level between the brakes and the sorting sidings.

If there are two sets of brakes one for « interval » braking and the other for « distance » braking, the point zone may be placed between the first and second set of brakes in a slight gradient corresponding to the running resistance of a good runner (track and curve resistance);

c) the rail brakes must be efficient enough to give the necessary braking effort to all wagons and cuts of wagons which come along. In addition they must be able to be operated at a distance and also accurately;

d) the points should be placed in such a manner that the point zone is as small as possible. The first point should be as near as possible to the top of the hump.

The tracks should be so grouped together that from each point the same number of tracks will branch off;

e) In order to shorten the occupation time of the points :

α) quick operating point operating gear should be used;

β) the first points, which have to be thrown often, should be operated by the wagons themselves;

f) In order to be able to regulate the humping speed accurately, the yard master must :

α) be able to enter into direct communication with the driver of the humping engine, or

β) he must be able actually to control the train himself;

g) In order to keep unavoidable intervals as short as possible the reception sidings should be so arranged that the next train can be prepared for the shunt and can advance as far as the top of the hump whilst another train is still being shunted;

h) In order not to interfere with shunting operations through « closing up » in the sorting sidings, particularly efficient closing up engines will have to be used.

6. A real *high-capacity* yard can only be obtained if all the components are after careful calculation placed in proper relation to each other as regards their relative efficiency.

7. An installation must be economic, *i. e.*, its cost and its return must be in proper proportion to each other. It should only be built if a careful comparison of the annual expense with the economies to be obtained (working costs, upkeep, interest, amortisation and renewals) give definite promise of economic results.

CURRENT PRACTICE.

[621.132.3 (.42) & 621.132.8 (.42)]

High pressure locomotive with water tube boiler, London & North Eastern Railway.

Figs. 1 to 4, pp. 370 and 371.

This engine designed by Mr. H. N. Gresley, C. B. E., Chief Mechanical Engineer, London & North Eastern Railway, was built at the Darlington Works of that Company, but the boiler was built by Messrs Yarrow & Co., Ltd, of Glasgow.

As is well known, the ordinary type of boiler is not suitable for high pressures; therefore in building a locomotive with 450-lb. per square inch boiler pressure, it was essential to make a change in the type of boiler.

Mr. Gresley, therefore, in conjunction with Mr. Harold Yarrow, got out a type of water tube boiler suitable for locomotives which has been patented in their two names.

The boiler is built up with one steam drum 3 feet inside diameter by 27 ft. 11 5/8 in. long, and two water drums on either side of the firebox, each 18 inches in diameter and 11 ft. 5/8 in. long, and two other drums under the forward part of the boiler each 19 inches in diameter and 13 ft. 5 3/4 in. long. The forward drums are connected to the steam drum by 444 2-inch tubes and 74 2 1/2-inch tubes. The drums at the side of the fire grate are connected to the steam drum by 238 2 1/2-inch tubes and there is a back screen of 12 2 1/2-inch tubes. All the drums are solid forged and machined all over.

The use of a pressure of 450 lb. has necessitated a complete change in all the ordinary boiler practices; special forms of safety valves, regulator, water gauge and injectors have had to be provided. The safety valves, relief valves, reducing valves and regulators have been supplied by Messrs Cockburn & Co. of Glasgow, who specialise in high pressure boiler mountings. The main regulator admits high pressure steam to the high pressure steam chests, but to facilitate starting an additional supply of steam can be admitted through a small regulator, 1 inch in diameter, to the low pressure steam chest, but this must be closed directly the engine has got way. In order to prevent too high a pressure in the low pressure steam chests a pop safety valve is fitted which blows off at 200 lb. pressure.

For the auxiliary services such as the ejector, steam sanders, whistle, steam heater, injectors steam supplies, it will be noticed from the photograph (fig. 3) that there is a manifold above the firehole door from which the connection to the auxiliary services is taken. This manifold is supplied with steam by a reducing valve of Messrs Cockburn's make which maintains the steam pressure in the manifold to 200 lb. per square inch.

There are two injectors fitted to the boiler, one high pressure injector supplied by Messrs Gresham & Graven, and

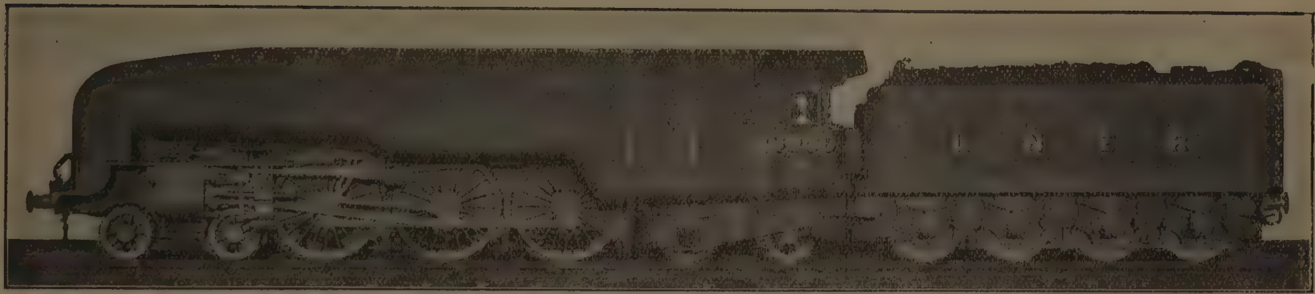

Fig. 1. — General view.

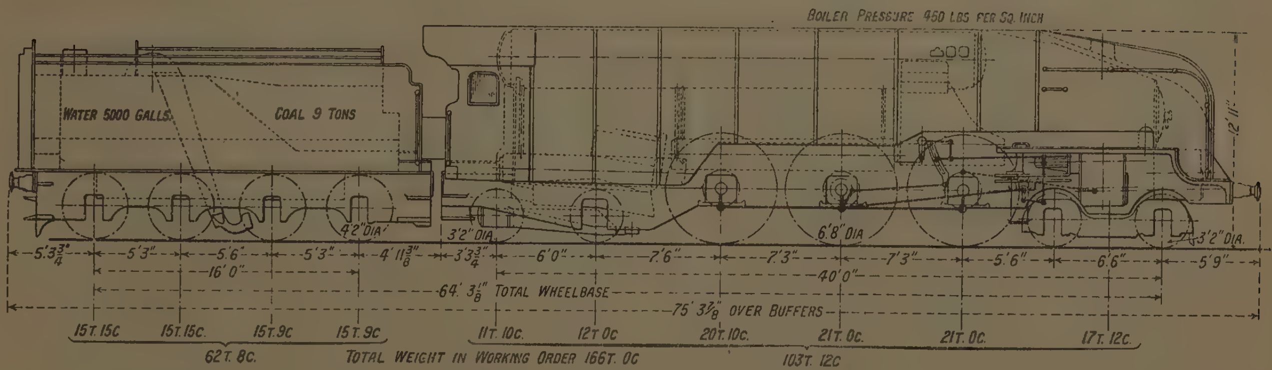

Fig 2. — Diagram and leading dimensions.

Fig. 3. — Trailing end.

Fig. 4. — Front end.

the other supplied with low pressure steam from the auxiliary steam manifold which was obtained from Messrs Davies & Metcalfe.

A special form of superheater has been fitted in the main flue on the boiler side of the regulator. The elements therefore are always under full steam pressure. The elements are connected to two forward headers located immediately in front of the water tubes.

The boiler is of ample capacity to supply the needs of the locomotive and when tested at the makers' works on a four hours' test at 450 lb. pressure gave an evaporation of 20 000 lb. per hour.

The combustion gases after passing between the tubes pass down each side of the boiler through two flues. There is an air space between those flues and the outer casing, and the air supply to the ashpan for combustion purposes is taken through this air space, the object being to preheat the air, also to prevent the outer casing of the boiler from becoming overheated. The intake is at the front of the smokebox through a large rectangular hole in the centre and two smaller rectangular holes one on each side, and the air supply to the ashpan is controlled by means of a damper; if necessary, cold air can be admitted to the ashpan through the front damper, but this damper is intended primarily for the removal of ashes, but it is expected that sufficient preheated air will be obtained to meet the combustion requirements.

One of the difficulties in connection with the water tube boiler to be expected will be due to the formation of scale, and in order to overcome this, the feed water is introduced in the forward portion of the steam drum where there are no water tubes. A weir extends across the bottom half of the drum at the back of this space over which all water which is supplied to the boiler for evaporation purposes has to pass. The feed water is delivered into the forward space by means of heater injectors which it is anticipated will raise the temperature of the water to something over 400° F. At such a temperature it is hoped that the greater part of the scale and impurities in the water will be thrown down in this space.

Means are provided for blowing off scale or sludge in this forward portion of the boiler without interfering with the water in the evaporative portion of the boiler.

The front end of the engine is of novel design which is necessitated by the fact that the boiler is built to the extreme limit of the gauge; therefore it is not possible to have a chimney of the ordinary pattern projecting above the top line of the boiler.

Before arriving at the shape of the front end experiments were carried out at the City & Guilds Technical College in conjunction with Professor Dalby by having a wooden model of the engine in the wind flume through which air was passed at about 50 miles per hour, and powdered chalk was projected through the chimney. The contour of the front of the smokebox has been so arranged that the steam and smoke escaping from the chimney should be thrown upwards and not interfere with the driver's vision from the cab.

The engine is a four-cylinder compound, having two high pressure cylinders each 12 inches diameter and 26 inches stroke, driving on the front coupled axle.

These cylinders are placed very close together, being only 14-inch centres, the object of bringing them together being to have a large bearing for the axleboxes. This arrangement has necessitated the designing of a new form of crank with a single central web.

The cylinders, steam chests and low pressure receiver are made of one steel

casting, the cylinders being lined with a cast iron liner of a special composition.

The low pressure cylinders are situated outside the frames and are standard with the cylinders used on the *Pacific* engines, being 20 inches in diameter by 26 inches stroke.

The connecting rods, coupling rods, etc., are standard with those used on the *Pacifics.*

There are two sets of valve gear operating the four valves. Walschaerts valve gear is fitted to the outside cylinders and the valves of the inside high pressure cylinders are operated by means of rocking shafts.

The inside arm of the rocking shaft is slotted and carries a die block to which the valve rod is attached. It is possible to vary the cut-off of the high pressure cylinders independent of that of the low pressure cylinders by raising or lowering the die block in the slot. This arrangement is novel and has been patented by Mr. Gresley.

There are 2 sets of steam reversing gear, one to control the Walschaerts valve gear and the other to control and vary the cut-off of the high pressure cylinders.

The steam valves operating these reversing gears are operated from the footplate by Telemotors. The cylinder cocks are also controlled by Telemotors made by Messrs McTaggart Scott, of Edinburgh.

The trailing end of the engine is carried on two axles, the forward one being similar to that in the *Pacific* engine, having Cartazzi axleboxes, and the rear one fitted to a bissel truck with the centre located immediately on the front of the firebox. It was not possible to fit a bogie to the trailing end.

The engine in working order weighs 103 tons 12 cwt., and it is interesting to note that this actual weight varied 5 cwt. from the estimated weight before the engine was built.

The engine has not been built in order to secure increased power or increased speed as compared with the *Pacific* engines, the whole object of the introduction of high pressure steam being to promote fuel economy. The engine is fitted with corridor tender of the standard type used on *Pacific* engines.

[625. 246 (.42)]

London and North Eastern Railway
20-ton goods brake van with ferro-concrete body.

Figs. 1 to 5, pp. 374 and 375.

A goods brake van with a body constructed of ferro-concrete has been turned out from the London & North Eastern Railway Shops at Temple Mills, to the design of Mr. H. N. Gresley, the Chief Mechanical Engineer.

The usual wooden body has been replaced by a structure of reinforced concrete, the design of which was prepared in conjunction with Messrs K. Holst & Co., of Victoria Street, London, S. W., who have also carried out the actual work

Fig. 1.

Fig. 2.

of construction in the London & North Eastern Railway Shops. The weight of the concrete is such that the full tare can be obtained without fitting the usual cast iron ballast weights.

For the purpose of this experiment a standard steel underframe was used, certain of the main members being embraced by the concrete floor to obviate the use of holding-down bolts.

The standard body equipment has been provided, bolts for securing the fittings being anchored in the concrete.

The initials « N E » and vehicle num-

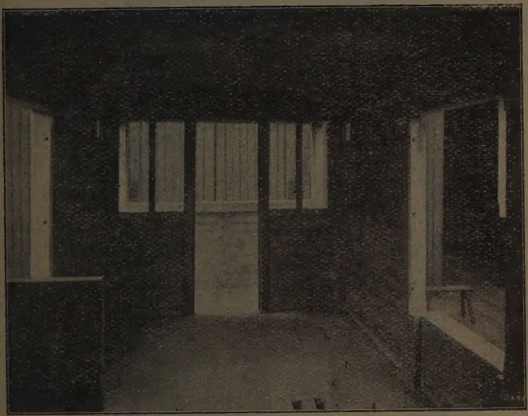

Fig. 3.

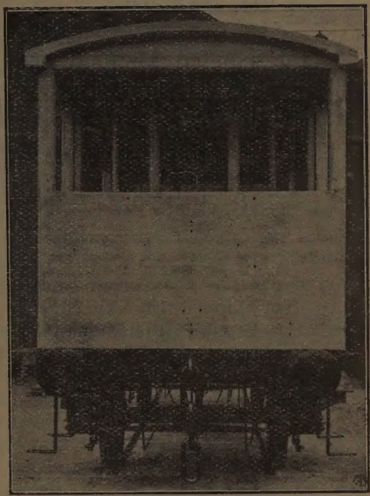

Fig. 5.

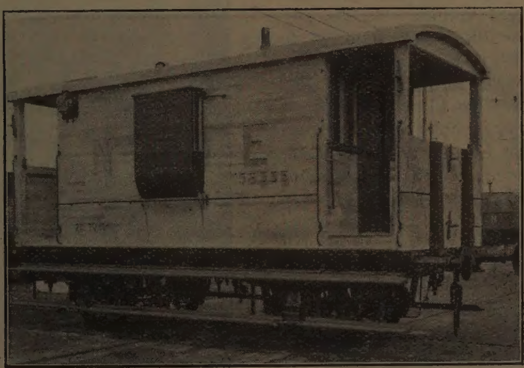

Fig. 4.

ber are moulded in the concrete and the whole of the body structure is finished in the London & North Eastern Railway standard colours.

The five photographs show interior and exterior of van finished and during construction.

[621. 132.5 .42)]

The London Midland and Scottish Railway Company's locomotive

having a boiler pressure of 900 lb. per square inch.

Fig. 1, p. 376.

Very interesting experiments are being carried out at the present time to make the steam locomotive definitely more efficient. In some of these, attempts are being made to extend the cycle at the low pressure end of the scale : this necessarily involves the use of the turbine with which alone is it possible to condense and as a consequence the use of the exhaust for creating the draught has to be abandoned. In the remainder the object is to improve the working efficiency by raising the initial temperature and also the pressure much above present values.

The locomotive illustrated belongs to the second group. It has been designed by Sir Henry Fowler, K. B. E., Chief Mechanical Engineer of the London, Midland & Scottish Railway in collaboration with the « Superheater Company Limited », who are the licensees of the Schmidtsche Heissdampf Gesellschaft of Kassel.

The locomotive is a three-cylinder compound, the single high pressure cylinder being supplied with steam at a pressure of 900 lb. per square inch.

The boiler is based on the Schmidt high pressure system and consists of three distinct parts working at different pressures. The first forms a closed circuit consisting of water tubes forming the firebox. It contains pure (distilled) water and works at a pressure which may be as high as 1 400 to 1 800 lb. per square inch and serves to convey the heat to the second part which forms the high pressure boiler, supplying steam to the high pressure cy-

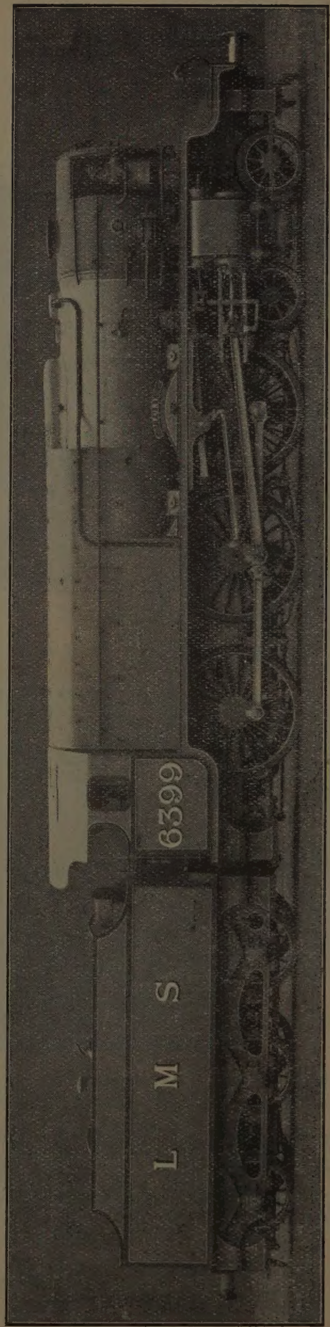

Fig. 1.

linder. The second part consists of a nickel chrome steel drum not directly heated by the flames or hot gases. The third part consists of a cylindrical barrel with smoke tubes in the position occupied by the barrel of the usual design of boiler. It is designed for a pressure of 250 lb. per square inch.

The low pressure boiler is fed by two injectors, one using live and the other exhaust steam. The high pressure drum is fed by a feed water pump taking water from the low pressure barrel.

The steam from the high pressure boiler passes through superheater elements in the lower smoke tubes, that from the low pressure boiler through elements in the upper rows.

Although working on a quite different principle, the locomotive has very much the same appearance as the usual locomotive, its outside lines being almost the same as those of the « Royal Scot ». The steam exhausted from the high pressure cylinder is mixed with steam at 250 lb. per square inch from the low pressure boiler and is then used in the two low pressure cylinders.

When the pressure in the 900-lb. per square inch boiler rises more quickly than the pressure in the low pressure boiler, steam from the former can be transferred to the latter.

The trials with this locomotive will be carried out during 1930.